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REVISION 3

NAVAL SHIPS' TECHNICAL MANUAL

CHAPTER 997

DOCKING INSTRUCTIONS AND ROUTINE WORK IN DRY DOCK

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CHAPTER 997

SECTION 1.
GENERAL INSTRUCTIONS

997-1.1 AUTHORITY AND RULES

997-1.1.1 DOCKING NAVAL SHIPS IN NAVAL DOCKING FACILITIES. Authority is vested in Commanders of naval shipyards and Commanding Officers of naval stations, floating dry docks, and advanced bases, to dock naval ships and craft, including floating dry docks, in naval docks and vertical lift facilities. This docking may be accomplished without prior reference to the Naval Sea Systems Command (NAVSEA) and subject only to the authority granting the availability. As used in this chapter, the term naval denotes of or pertaining to The United States Navy .

997-1.1.2 DOCKING SHIPS OTHER THAN NAVAL SHIPS IN NAVAL DOCKING FACILITIES. Commanders of naval shipyards and Commanding Officers of naval stations, naval floating dry docks, and advanced bases are authorized to dock ships belonging to other government departments, state or local governments, foreign governments, private parties, and morale, welfare and recreational activities in accordance with Article 0749, United States Navy Regulations, 1979 , without reference to NAVSEA in cases where authority for performing docking of the ships has been previously obtained from the owner of the ship. The authority of NAVSEA will be required for all docking of such ships where authority has not been previously obtained from the owner of the ship.

997-1.1.3 DOCKING NAVAL SHIPS IN NON-NAVAL DOCKING FACILITIES. In accordance with the terms of established contracts, authority is vested in Supervisors of Shipbuilding (SUPSHIPS) to dock naval ships and craft in non-naval dry docks, floating docks, vertical lift platforms, and other facilities specifically designed for that purpose. Such dockings may be accomplished without prior reference to NAVSEA and are subject to the authority granting the availability.

997-1.1.4 DOCKING FACILITY CERTIFICATION. All commercial and naval docking facilities docking naval ships shall be certified in accordance with MIL-STD-1625, Safety Certification Program for Drydocking Facilities and Shipbuilding Ways for U.S. Navy Ships . The purpose of this certification is to ensure the safety of naval ships during docking/undocking evolutions and while in the docking facility. In this context, a naval ship is defined as a ship listed in NAVSEA 250-574-8, Naval Vessel Register/Ships Data Book .

997-1.1.5 DOCKING UNDER COGNIZANCE OF SUPSHIPS. When docking new construction naval ships and naval ships undergoing conversion in commercial yards under cognizance of SUPSHIPS, the provisions of NAVSEA 0900-LP-000-3010, Ship Acquisition Contract Administration Manual , apply. When docking naval ships for repair or overhaul in commercial yards under cognizance of SUPSHIPS, the provisions of NAVSEA 0900-LP-079-5010, Ship Repair Contracting Manual, apply. References throughout this chapter to the SUPSHIPS Representative indicate administrative tasks only and do not imply operational authority or control over the contractor's certified dockmaster. Statements in the text that the contractor shall ... are based on prudent drydocking practices and do not imply limitations on, or responsibility for, the actions of the contractor's Dockmaster.

997-1.2 DOCKING INTERVAL

997-1.2.1 GENERAL POLICY AND EXCEPTIONS. The policy of NAVSEA, in regard to the docking intervals of naval ships and service craft listed in the following paragraphs, shall be generally adhered to. However, variation in docking intervals of 3 months either way is permissible. Emergency or unscheduled dockings shall be carried out at the discretion of the Commanders of naval shipyards, and Commanding Officers of naval stations, naval floating dry docks, and advanced bases, without prior reference to NAVSEA.

997-1.2.2 STEEL HULL SHIPS IN ACTIVE STATUS. Docking interval for steel hull ships in active status is as follows.

997-1.2.2.1 Normal Docking Interval. The normal docking interval for cleaning and painting the underwater hull is, in general, not to exceed 3 years.

997-1.2.2.2 Additional Dockings. Steel hull ships in an active status shall be given an additional docking between overhauls under the following conditions:

a. When painted with antifouling coatings (other than those in accordance with NSTM Chapter 631, Preservation of Ships in Service (Surface Preparation and Painting)) which are formulated to retard fouling for approximately 3 years.

b. When it is definitely known that undue fouling of the hull has taken place, as indicated by underwater inspection, increase of fuel consumption, or loss of speed.

c. When previous experience or dockings, or current underwater inspections by divers, indicate that underwater fittings will require overhaul prior to the next regularly scheduled docking of the ship.

d. When the ship is a submarine, in which case an interim docking shall be performed approximately halfway between regular overhaul periods.

997-1.2.2.3 Extension of Period Between Dockings. In lieu of the present 3-year interval, the period between dockings may be extended to a maximum of 5 years for steel hull surface ships, without NAVSEA authority, provided the following conditions exist:

a. Impressed current cathodic protection, installed for hull protection, has performed satisfactorily since installation.

b. After a 3- and 4-year interval, a detailed underwater television scan of the sonar dome, propeller shaft, and propeller reveals no apparent damage and a concurrent check of after stern tube and strut bearings establishes that clearances are within tolerance.

c. Excessive fouling, resulting in unacceptable ship performance, is removed by waterborne cleaning. (Particular attention shall be given to sonar domes, propeller shafts, and to suctions and discharges.)

d. Block location in dry dock is rotated on sequential dockings among the three docking positions so that the complete hull is painted with no skipped areas in each 15-year (or shorter) interval.

e. Based on past experience, it can be reasonably assumed that underwater fittings will not require overhaul prior to the next scheduled docking of the ship.

NOTE

Any extension beyond 5 years for ships meeting these criteria, or beyond 3 years for active steel hull surface ships not meeting the criteria requires NAVSEA approval. A copy of the request shall be forwarded to the Chief of Naval Operations (CNO) (Code OP 43).

997-1.2.3 STEEL HULL SELF-PROPELLED SERVICE CRAFT IN ACTIVE STATUS. Docking interval for these craft is as follows:

997-1.2.3.1 Normal Docking Interval. The normal docking interval for cleaning and painting the underwater hull is, in general, not to exceed 4 years. Reference shall be made to NSTM Chapter 034, Service Craft .

997-1.2.3.2 Additional Dockings. Steel hull self-propelled service craft in an active status shall be given an additional docking between overhauls under the following conditions:

a. When painted with antifouling coatings (other than those in accordance with NSTM Chapter 631, Preservation of Ships in Service (Surface Preparation and Painting)) which are formulated to retard fouling for approximately 3 years.

b. When it is definitely known that undue fouling of the hull has taken place as indicated by underwater inspection, increase of fuel consumption, or loss of speed.

c. When previous experience or dockings indicate that underwater fittings will require overhaul prior to the next regularly scheduled docking of the craft.

997-1.2.3.3 Extension of Period Between Dockings. Any extension beyond 4 years requires approval of the CNO (Code OP 43).

997-1.2.4 STEEL HULL NON-SELF-PROPELLED SERVICE CRAFT IN ACTIVE STATUS. Non-self-propelled service craft with steel hulls (except floating dry docks) in an active status shall be docked, cleaned, and painted at 4 year intervals, if they contain machinery, and at 6 year intervals if they do not contain machinery (see also NSTM Chapter 034 . Any further extension requires approval of CNO (OP 43).

997-1.2.5 STEEL HULL SHIPS AND SERVICE CRAFT IN INACTIVE STATUS. Except for floating dry docks, docking of inactive ships shall be conducted in accordance in Table 997-1-1. Terms used in Table 997-1-1 are defined as follows:

a. Thin Hull Ships . Thin hull ships are surface ships and service craft with plating less than 1/2-inch thick (20.4 pounds) at the waterline.

b. Heavy Hull Ships . Heavy hull ships are surface ships and service craft with plating 1/2-inch thick or greater at the waterline.

c. Freshwater Sites . Inactive Ship Maintenance Facility (INACTSHIPFAC) Philadelphia has freshwater berthing sites.

d. Seawater Sites . INACTSHIPFAC Bremerton, Mare Island, and Portsmouth have seawater berthing sites.

e. Class B and C Ships . These classifications refer to maintenance categories of inactive ships established by the CNO.

Table 997-1-1. DOCKING INTERVALS FOR INACTIVE STEEL HULL SHIPS AND SERVICE CRAFT

Berthing Site Environment	Type Hull	Under Cathodic Protection (years)	Not Under Cathodic Protection (years)
Seawater	Thin	15*	5
Fresh water	Thin	15*	6
Seawater	Heavy	15*	7
Fresh water	Heavy	15*	8
Seawater	Submarine	15*	5
Fresh water	Submarine	15*	6

*Ships under impressed current cathodic protection with a history of satisfactory potential readings, and having waterline area which appears satisfactory upon inspection after 15 years, may be extended to a 20 year docking interval.

NOTE

Class B and C ships shall be scheduled for docking in accordance with the intervals given in Table 997-1-1. If funds available in any particular fiscal year are not sufficient to provide for the docking of all scheduled ships, class C ships shall have the lowest docking priority and shall be recommended for deferral as necessary.

997-1.2.6 WOODEN SHIPS AND SERVICE CRAFT IN ACTIVE OR INACTIVE STATUS. Except for floating dry docks, plans for docking wooden ships and service craft shall be made compatible to the docking intervals provided in Table 997-1-2.

997-1.2.7 FLOATING DRY DOCKS. The drydocking interval for floating dry docks shall not exceed the period specified in MIL-STD-1625, Safety Certification Program for Drydocking Facilities and Shipbuilding Ways for U.S. Navy Ships , as summarized in Table 997-1-3.

NOTE

Any extension for service craft and floating dry docks is subject to CNO (Code OP 43) approval.

997-1.3 UNDERWATER INSPECTION AND CLEANING

997-1.3.1 UNDERWATER INSPECTION. The need for underwater cleaning must be based on underwater inspection when use of torsion meters or other instrumentation to estimate speed loss at full power is not feasible. Following the cleaning process, an inspection shall be carried out to provide feedback on paint system impact. A change in color of paint may occur when cleaning; this is normal and indicates exposure of fresh antifouling or anticorrosive paints. The results of an underwater inspection may, as the situation warrants, be documented on form NAVSEA 4730.

Table 997-1-2. DOCKING INTERVALS FOR ACTIVE AND INACTIVE WOODEN SHIPS AND SERVICE CRAFT

Environment	Unsheathed Wooden Hull Ships	Sheathed and Planked with Pressure Treated Wood	Sheathed with Copper
Water heavily infested with shipworms	Every 3 to 6 months	Every 6 to 9 months	Every 12 months
Normal seawater	Every 12 to 20 months	Every 12 to 20 months	Every 20 months
Fresh water	Every 5 years	Every 5 years	Every 5 years

Table 997-1-3. UNDERWATER HULL SURVEY INTERVALS FOR FLOATING DRY DOCKS

Type Construction	Underwater Hull Survey Internal (Years)
Steel	5/10 (see note 1)
Timber	5/10 (see note 2)
Concrete	5/10 (see note 3)

NOTE

See MIL-STD-1625, Safety Certification Program for Drydocking Facilities and Shipbuilding Ways for U.S. Navy Ships, for further detailed guidance; this table is a summary only.

997-1.3.2 CLEANING INTERVAL. Since the difficulty of cleaning, the time involved, and the risk to the protective paint are directly proportional to the extent of a calcareous fouling (barnacle accumulation), the underwater cleaning operation shall not be unduly delayed. The decision to clean the hull and steel sonar dome shall be based upon observance of grasses and slimes prior to barnacle formation. Experience at the activity involved will dictate how often to conduct underwater inspection, based upon ship operations and environment. A 3-month interval is recommended as a starting point. Propeller fouling shall not be allowed to reach a point beyond initial appearance of calcareous growth.

997-1.3.3 CLEANING METHODS. Scrubbing of ships' bottoms and sonar domes, by divers using approved equipment and procedures, shall be permitted when authorized by the administering naval activity. When cleaning and removal of fouling are performed, care shall be exercised so as to remove as little as possible of the paint coating. Cleaning methods should be restricted to those using rotary polypropylene brushes or equivalent (it is anticipated that calcareous removal on the hull will be incomplete, but this is justifiable due to lower risk of paint damage.)

997-1.4 DOCUMENTATION

997-1.4.1 DOCKING REPORT. Docking reports shall be prepared and submitted as follows.

a. When a naval ship, service craft, or floating dry dock is docked in a naval docking facility, a docking report (NAVSEA 9997/1 and, as appropriate, NAVSEA 9997/2 - NAVSEA 9997/5) shall be prepared by the docking facility in accordance with instructions contained in NAVSEA 9997/1. The report shall be furnished to the Commanding Officer of the ship for placement in the ship's file. Copies shall be forwarded to the appropriate Type Commander and Planning Yard. A copy of NAVSEA 9997/4 shall also be forwarded to NAVSEA 03X41 (Bearings and Seals Technology Branch). Preparation of docking reports for boats and landing craft, except LCUs, is not required.

b. When a naval ship is docked in a non-naval docking facility, the docking report shall be prepared under the technical guidance of a qualified naval representative. Where a qualified naval representative is not specifically assigned to such a docking facility, the report shall be prepared and submitted by the Engineering Officer of the ship to the same distribution as above.

c. Type Commanders shall furnish one copy of the last two overhaul docking reports and interim docking reports (if any) to the docking facility 60 days prior to the start of availability.

997-1.4.2 INSTRUCTIONS FOR DOCKING FACILITIES. Each naval shipyard, station, or activity having docking facilities, or the Commanding Officer of a floating dry dock in commission, shall issue appropriate instructions covering the use, safety precautions, and docking procedure applicable to the available facilities, for the guidance of the shipyard, docking facility, and ship personnel. Each SUPSHIPS Representative docking naval ships in commercial yards which utilize docking facilities shall ensure that the commercial yard issues appropriate instructions covering the use, safety precautions, and docking procedures applicable to the available facilities, for guidance of the shipyard, docking facility and ship personnel in accordance with NAVSEA 0900-LP-079-5010, Ship Repair Contracting Manual . Special care shall be taken to observe the precautions listed in the appropriate operating manual for a particular floating dry dock.

997-1.4.3 DOCKING LOG BOOK. A log book shall be maintained at the main control station for graving docks, floating docks, and vertical lifts in which all pertinent details shall be recorded regarding the use of the facility. The log book shall contain data as to power employed, time of beginning and ending of each important event, and particulars affecting the ship in dock or on the lift, including sill times, casualties, drafts of ship and dry dock (floaters), water over the keel blocks on docking and on undocking and name of Docking Officer or contractor's Dockmaster in charge of the docking/undocking evolution. Also, vital machinery out of commission, tides, and wind speed and direction during the docking/undocking evolution shall be recorded.

997-1.5 OPERATING THE DOCKING FACILITY

997-1.5.1 OPERATING MANUALS, DATA BOOKS, AND DAMAGE CONTROL BOOKS. If operating manuals, data books, and damage control books that have been prepared or approved by NAVSEA are provided for a specific dock or vertical lift, the procedures given shall be followed to ensure safe and reliable operation of the dry dock.

997-1.5.2 VITAL SYSTEMS. Vital system docking requirements are as follows.

CAUTION

Without satisfactory operational vital systems and elements, the safety of the dock and the docking evolution are in jeopardy and it is not prudent to undertake a docking evolution.

a. It is mandatory that the Commanding Officer, Officer-in-Charge, Docking Officer, contractor's Dockmaster, or any other person assigned responsibility of docking ships, ensure that the vital systems and equipments required for safe docking of ships be operational for each docking and undocking evolution and other evolutions requiring transfer of ballast water from one tank to another.

b. The systems and elements considered vital to safe operation of a floating dry dock, and required to be available and operable before starting a floating drydock evolution, are:

1. Reliable and functioning ballast level and draft indicating system
2. Functional wing wall deflection indicating system or equivalent method on both wing walls
3. Reliable and properly functioning two-way communications system to all manned stations during drydock evolutions
4. Proper manning of all primary and secondary stations with adequately trained personnel to perform the evolutions in process, including provision for manual backup of motorized valves
5. Reliable and properly functioning ballast system
6. Primary electrical power source capable of operating all vital systems and a secondary (backup) power source capable of operating (as a minimum) 50 percent of all vital systems, including fire pumps (if installed).
7. Positive method of visually determining position of all ballast valves.

997-1.5.3 SUPERVISION. The operation of floating dry docks must be supervised at all times by a Docking Officer in the case of a naval facility, or a Dockmaster in the case of a commercial facility. The Docking Officer or contractor’s Dockmaster must be fully qualified in accordance with current instructions. If, in the opinion of the Commanding Officer, Officer-in-Charge, Docking Officer, or contractor’s Dockmaster, the conditions of paragraph 997-1.5.2 are not fulfilled, it should be concluded that any further docking or ballast transfer operations are unsafe, and docking operations shall be terminated at once and suspended until satisfactory corrective action has been accomplished.

997-1.5.4 CHARGES. Charges for the use of docking facilities will be made in accordance with the instructions in the Navy Comptroller Manual, Volume III .

SECTION 2.
DOCKING PROCEDURE

997-2.1 RESPONSIBILITY FOR DOCKING

997-2.1.1 The responsibilities of the Commanding Officer and the Docking Officer in docking ships are set forth in Article 0752, United States Navy Regulations, 1979. All dockings in naval facilities shall be supervised by a Navy officer or Navy civilian who has been given specific training and has been certified as a qualified Docking Officer in accordance with applicable Naval Sea Systems Command (NAVSEA) instructions. In commercial facilities during drydockings there shall be a Representative of the Supervisor of Shipbuilding (SUPSHIP) on site who is qualified as a docking observer in accordance with NAVSEA instructions. When docking in commercial facilities, the SUPSHIP Representative shall ensure that the contractor’s Dockmaster is professionally qualified through training and experience and that his/her qualifications are a matter of record. The SUPSHIP Representative shall also ensure that the contractor is provided with the latest applicable docking drawings and a copy of the last two docking reports as indicated in paragraph 997-1.4.1.

997-2.2 ADVANCE PREPARATIONS FOR DOCKING

997-2.2.1 DOCKING INFORMATION FROM THE SHIP. The Commanding Officer of the ship shall furnish the Docking Officer or SUPSHIP Representative with the following information:

a. Place and date of last docking

b. Last docking position

c. Dates and file numbers of last two docking reports and interim docking reports (if any)

d. Number of days underway since last docking

e. General itinerary of ship movements (if not classified)

f. Paint history for last complete painting

g. History of touch-up painting

h. Tank sounding report

i. List of any relevant data for any alterations accomplished on the ship which may affect the docking operations but are not shown on the docking drawing

j. Data for use in carrying out stability calculations from Ship's Damage Control Book and Booklet of General Plans

997-2.2.2 DOCKING ARRANGEMENTS. Docking arrangements will be agreed upon during a pre-docking conference. This conference shall be attended by, as a minimum, the Commanding Officer and the Engineering Officer of the ship to be docked, and (if at a naval facility) the Docking Officer, or (if at a commercial drydocking facility) the SUPSHIP Representative and the contractor's Dockmaster. This conference shall be arranged sufficiently prior to the docking date to permit the incorporation of all details required in the docking. The following shall be considered and agreed upon:

a. Certification of the proposed docking facility in accordance with MIL-STD-1625

b. Availability of the latest corrected docking drawing, the last two docking reports and interim docking reports (if any) for the ship

c. Adequacy of the facility to dock the ship (physical dimensions, lifting capacity, vital systems operational (Refer to paragraph 997-1.5.2), and so forth)

d. Availability of properly qualified supervisory personnel (Refer to paragraph 997-1.5.3)

e. Details of the docking plan, including positioning of ship and blocks

f. Time and date of docking

g. Tugs and Pilots required for docking ships shall, if possible, be furnished by the Shipyard Commander from those regularly assigned to the shipyard. If tugs are not regularly assigned to the shipyard, tug service should be requested from the Naval Base Commander. If additional tugs are required, they shall be obtained by requisition under the appropriation supporting the docking establishment. All tug Captains and Pilots shall be thoroughly briefed by the Docking Officer or contractor's Dockmaster on regulations, instructions, and authority as applicable to the drydocking. It is imperative that all Pilots handling U.S. naval ships in and out of dry docks and vertical lift facilities follow the Navy regulation that the responsibility for control of the ship is vested in the Docking Officer or the contractor's Dockmaster from the moment the extremity of the ship first to enter the dock reaches the dock sill. Failure of Pilots and tug Captains to respond to the Docking Officer or contractor's Dockmaster during drydocking shall be cause for debarment from future naval ship drydocking functions.

h. Whether bow or stern of the ship is to enter the dock first.

i. Ship's drafts, trim and list (load items shall be so arranged as to bring ship into the docking facility with proper trim and list.)

j. In the case of a ship in commission, the shipyard shall request that the ship to be docked furnish working parties to handle lines, sound tanks, and attend hull openings. If the ship's crew is too small to furnish working parties, the Commanding Officer shall so inform the shipyard. Arrangements will then be made to obtain working parties from some other ship at the shipyard or to detail yard labor, as directed by the shipyard Commander. If the ship is out of commission or otherwise without a crew, working parties shall be detailed by the shipyard for the following tasks:
    1. To handle lines during the docking
    2. To sound all ship tanks 12 hours before the ship is docked (Reports of the soundings shall be forwarded to the Docking Officer or SUPSHIPS Representative before the docking operation commences)

k. Record of tank soundings before the ship is drydocked

l. Gangways to be used

m. Utilities to be furnished to the ship, such as electric power, steam, and water

n. Sanitary services to be provided

o. Garbage and refuse disposal facilities needed

p. Safety precautions for the docking facility and pumping plans or other instructions and operating directives for:
    1. Ballasting/deballasting floating dry dock with or without ship in basin
    2. Flooding/dewatering graving dock
    3. Lowering/raising of the vertical lift platform with or without ship
    4. Note that a minimum clearance of 12 inches between the floating dry dock and the harbor bottom shall be maintained at all times

q. Methods of communication between personnel at various docking stations on the floating dry dock, graving dock, or vertical lift, and on ship, tugs, and so forth

r. Use of divers for inspection during landing the ship

s. Availability of crane services

997-2.2.2.1 Using the resulting agreements on docking arrangements, and the operating procedures specified in the docking facility as approved Facility Certification report or Facility Recertification Report (as specified in MIL-STD-1625, Safety Certification Program for Drydocking Facilities and Shipbuilding Ways for U.S. Navy Ships), the following shall be prepared by the Docking Officer or the contractor's Dockmaster for use during docking operations for each ship:

a. Sequence and description of important steps

b. Pumping and flooding plan (where applicable)

c. Docking logs and checklists showing required data entries and verification signatures for the docking evolution

997-2.2.3 DOCK BLOCKING PREPARATIONS. The arrangement of blocking for a ship to be docked shall be made in accordance with the latest corrected docking drawing obtained from the planning yard.

997-2.2.3.1 Docking Drawing. The Docking Officer or SUPSHIPS Representative shall ascertain that the docking drawing is correct and that all underwater projections, for which blocks must be omitted or specially arranged, are shown. A docking position shall be selected which will enable cleaning and painting of those areas which had been in contact with blocks during preceding dockings. The Docking Officer or SUPSHIPS Representative shall also ascertain the nature of any planned underwater work, and have blocks arranged accordingly. When docking in a naval shipyard, the alternative docking drawing developed in accordance with NAVSEA Uniform Method and Standard (0908-401) and 0908-402) shall be used whenever possible.

997-2.2.3.2 Clearance Between Ship and Blocks. The Docking Officer or the contractor's Dockmaster shall determine that at the scheduled docking time there will be ample water over the blocks to permit the ship to enter the dry dock and to prevent the ship landing prematurely due to, for example, a rapidly falling tide. This determination shall be made by calculating or having calculated to his satisfaction the height of the tide with respect to the height of the tops of the drydock blocks and the ship's deep draft. In addition, consideration shall be given to the maximum height of the keel blocks and side blocks as well as the hull projections in determining adequate safe clearance over the blocks.

997-2.2.3.2.1 The Docking Officer or the contractor's Dockmaster shall determine that for the planned docking evolution there shall be ample clearance between the sides of the ship (and its appendages) and the docking blocks.

997-2.2.3.2.2 A minimum clearance of 12 inches between the ship (or nearest appendage) and the docking blocks shall be maintained during the docking evolution. Also, in floating dry docks a minimum clearance of 12 inches shall be maintained between the dock and the harbor bottom. Clearances less than 12 inches pose a significant risk which is acceptable only in emergency situations.

997-2.2.3.2.3 Note that tidal changes do not affect the amount of water over the blocks in a floating dry dock. However, tidal changes will affect the amount of water under a floating dry dock.

997-2.2.3.3 Checks on Blocking Settings. Before flooding the dock, the Docking Officer or contractor's Dockmaster shall check the blocks, paying particular attention to the following factors:

a. Location of first (after) keel block (or location of the aft lifting strap and forward lifting strap in the case of straddle cranes)
b. Location of the square marks on the coping for placing the stem and stern of the ship preparatory to landing
c. Location of fore-and-aft centering markers
d. Side clearance of ship
e. Rudder and propeller clearances above dock floor, and space for shaft removal
f. Offsets from center line or from set keel blocks and side blocks

g. Height of reference plane from which block heights are measured, heights at set side blocks and keel blocks if ship's keel has excessive departure from level plane

h. Location and heights of hauling side blocks, if used

i. Special blocking arrangements for hull projections, hull openings, and planned underwater work

j. Crane clearances

k. Removal of unnecessary blocks

l. The level of the keel blocks for the length of the ship's keel, checked by eye to ensure that there are no unduly high blocks

m. The reference plane for blocks, checked with a transit

997-2.2.3.4 Soft Caps. As shown in Figure 997-2-1, soft caps form the top of keel blocks and side blocks (side blocks are also known as bilge blocks). Keel block soft caps shall measure 2 inches minimum to 6 inches maximum in thickness. Side block soft caps shall measure 2 inches minimum to 6 inches maximum in thickness on their short corners but do not have a maximum thickness limitation on their long corners (in order to accommodate a steeply rising bilge section of the drydocked ship). Care must be exercised to ensure that the thicknesses of all soft caps in a blocking system are proportional. For example, a 6 inch soft cap on a keel block and a 2 inch soft cap on a side block are not proportional. This situation would permit disproportionate compression of the keel block which would result in a higher load being exerted on the ship by the side block and possible overstressing of the ship's hull.

997-2.2.4 SHIP'S LIST. It is difficult to dock a ship which has a list. If a ship has a list, every effort shall be made to remove it before docking. In the majority of cases, list is caused by either an inherent asymmetrical condition of the ship or asymmetrical loading. A ship may be docked with a very small list. Refer to paragraph 997-2.5.6 for other considerations with regard to ship's list.

997-2.2.5 SHIP'S TRIM. As with list, ship's trim should be minimized prior to docking. Refer to paragraph 997-2.5.5 for other considerations with regard to ship's trim.

997-2.2.6 PROPELLERS, RUDDERS, AND PROJECTING DEVICES. From the time the extremity of the ship first to enter the dry dock crosses the sill of the dock going in, until that extremity crosses the sill going out, the propellers must be set in the optimum position and not be turned over unless authorized by the Docking Officer or contractor's Dockmaster. On those ships being moved entirely by tugs and lines from shore, the propellers must be kept in the docking position and the rudder kept locked amidships. Operating devices that project below the keel are to be kept in the retracted position wherever possible.

997-2.2.7 FACILITY CLEAN-UP. Prior to docking, all debris, blast grit, staging, equipment, floatable objects, and similar materials which may endanger or interfere with the docking operation shall be removed from the docking facility.

997-2.3 THE DOCKING OPERATION

997-2.3.1 FORMALITY OF DOCKING FACILITY OPERATING PROCEDURES. One of the requirements of MIL-STD-1625 for certifying docking facilities for docking naval ships is that complete operating instructions and procedures for the docking facilities be prepared and made available at appropriate stations. To minimize the possibility of inadvertent drydock floodings, the following actions shall be accomplished:

1. Drydock operating procedures shall be in step-by-step detail and shall be followed verbatim. These procedures shall include valve and control system lineup check sheets for use in prerequisite checks of dock systems status before the step-by-step docking operations are initiated. These check sheets shall include requirements for independent checks of the valve and control positions by two individuals.
2. Formal prerequisite lists for the docks shall be used for all docking/undocking or dock flooding/dock pump down operations. Similarly, formal prerequisite lists for the ship shall be utilized when a naval ship is involved in the operations.
3. Verification signature requirements, similar to those required by NAVSEA INST 9210.23 for naval nuclear work, shall be included for critical steps in the procedures and in the prerequisite lists. For example, satisfaction of prerequisites, including valve lineups, shall be documented by verification signatures. In addition, completion of a critical procedure step, or series of steps, shall be documented by verification signatures. It is not intended that the requirement for verification signatures interrupt a sequential operating evolution in which continuity of the sequence is mandatory.
4. Methods of communication among the appropriate personnel shall be included in these procedures.

997-2.3.2 PRESENCE OF DOCKING OFFICER, SUPSHIPS REPRESENTATIVE, AND CONTRACTOR'S DOCKMASTER. The Docking Officer (if at a naval facility) or the SUPSHIP Representative and the contractor's Dockmaster (if at a commercial drydocking facility) shall be present at the time the floating or graving dock is flooded or the vertical lift facility is raised and shall remain at the dock or vertical lift facility until all blocks are well covered to make sure that no blocks come adrift or are misplaced so as to endanger the ship when landing.

997-2.3.2.1 The preferred station for the Docking Officer or contractor's Dockmaster at the time of docking is on the windward side of the dock rather than on the ship being docked in floating or graving docks. This station enables the Docking Officer or contractor's Dockmaster to be present during all preparations for docking.

997-2.3.2.2 For dockings on vertical lifts the preferred stations for the Docking Officer or contractor's Dockmaster at the time of docking is at the windward side of the vertical lift facility's side platform.

997-2.3.2.3 In certain situations, it may be advantageous for the Docking Officer or contractor's Dockmaster to take station on board the moving ship. An example is one ship moving alongside another when docking in a floating or graving dock where the lines must be handled by the stationary ship.

997-2.3.3 STATIONING OF PERSONNEL. Prior to the arrival of the ship at the dock, or vertical lift facility, the Docking Officer or contractor's Dockmaster shall have instructed various personnel as follows:

a. The ship as to the duties of the crew members aboard who will handle docking lines aboard the ship.
b. The dockside working party as to their duties in handling lines.

997-2.3.3.1 The Docking Officer or contractor's Dockmaster shall verify that riggers are properly stationed, that all lines are properly laid out on the dockside, and that drydock lifeline stanchions have been removed as necessary.

997-2.3.3.2 The Docking Officer or contractor's Dockmaster shall also verify that all stations are adequately manned; that pump, winch, or crane operators and shipwrights are at their stations; and that all necessary equipment is at hand.

997-2.3.4 WEATHER AND TIDAL CURRENTS. Wind and storms are hazards to docking operations. Winds of high velocity cause a serious handling problem for ships having a large sail area. Also, high winds can preclude the safe operation of floating dry docks, with their large wing wall sail areas. When winds are high, but safe operations are still practicable, it may be necessary to reassign line handlers and working party members so that there will be more lines on the windward side. During preparation, the tidal current should be observed and checked with current tables. The docking shall be delayed, cancelled, or postponed if the Docking Officer or the contractor's Dockmaster is not certain that the operation can be safely completed.

997-2.3.5 DRAFT READINGS. As the ship approaches the dock, the Docking Officer or contractor's Dockmaster shall have the draft readings observed to ensure that the drafts are as expected. Verification of the drafts shall be made by actual measurement in those cases where draft marks are not clearly identifiable.

997-2.3.6 TRANSITION FROM SHIP OR TUG PROPULSION TO HANDLING BY LINES. As the ship approaches the dock, heaving lines from the ship are attached to the shore lines which are then drawn up and made fast on the ship. Depending on the size of the ship and the shape of the fender piers at the entrance to the dock, it may be necessary to stop the ship to permit tugs to cast off.

997-2.3.6.1 The ship's speed shall in any case be kept minimal, because a ship moving too fast over the blocks may knock the blocks over.

997-2.3.6.2 The Docking Officer or contractor's Dockmaster shall direct handling of lines to ensure the safe entrance of the ship into the dock. In general, breast lines and spring lines shall not be led on the dock ahead of their position on the ship but shall be kept abreast or abaft. When two spring lines lead from one bow or quarter, one should lead over a bollard or cleat while the other is being shifted. Breast lines should be shifted, one at a time on either side, while all other lines are led over bollards or cleats. In docking small ships, considerable latitude is allowable in this respect, subject to the ship being kept fully under control.

997-2.3.7 EXCHANGE OF RESPONSIBILITY AND OPERATIONAL CONTROL. As the extremity of the ship first to enter the dock reaches the dock sill, and the ship is pointed fair for entering the dry dock or vertical lift platform, the Docking Officer or the contractor's Dockmaster relieves the Commanding Officer of responsibility for the safety of the ship. At this point, the Docking Officer or the contractor's Dockmaster also relieves the Pilot of operational control of the ship and tugs (see Article 0752, United States Navy Regulations, 1979 .)

997-2.3.8 CENTERING THE SHIP. The Docking Officer or contractor's Dockmaster shall center the ship on the keel blocks, using centering bobs, sighting battens and other appropriate equipment. The ship shall be kept centered over the keel blocks during the pumping down or raising operations. Note that in some situations the ship may not be centered in the docking facility; off-center positioning in the docking facility may be necessary when performing certain work or when docking two or more ships in the same facility.

997-2.3.9 LANDING THE SHIP. Landing the ship is to be accomplished as follows.

997-2.3.9.1 General. When docking ships in a graving dock, the Docking Officer or contractor's Dockmaster shall direct the placing and sinking of the caisson and personally observe that it is properly seated.

a. When landing the ship, the Docking Officer or contractor's Dockmaster shall direct the pumping out operations and hauling of side blocks if necessary (for dockings in floating dry docks and graving docks) or the raising and final positioning of the platform (for dockings on vertical lift facilities).

b. It is mandatory to use divers during certain circumstances, such as when:
   1. Docking drawing is in question
   2. Ship is damaged
   3. Blocks are suspected of being damaged/moved during docking
   4. Shipyard adherence to the docking drawing is in question.

997-2.3.9.2 Shoring. Shores, when used, shall be placed in position only after the ship has landed fore and aft, but prior to the ship reaching its draft at instability. Should a shore buckle, the Docking Officer or contractor's Dockmaster shall stop pumping or raising operations, set up the next shore, and replace the buckled shore.

997-2.3.9.3 Draft. The Docking Officer or contractor's Dockmaster shall note the drafts on the ship and observe that the ship lands at the proper points with respect to the draft.

997-2.3.9.4 Lines. The Docking Officer or contractor's Dockmaster shall exercise care that positioning lines are not parted when the ship is about to land.

997-2.3.9.5 Stopping Operation. The Docking Officer or contractor's Dockmaster shall stop the drydock pumps or raising of the vertical lift platform, and, if necessary, reflood the dock or lower the platform in case:

a. The ship takes an undue list when landing

b. The ship lands before the water has dropped to the proper depth

c. A shore buckles (buckled shores shall be replaced, as indicated in paragraph 997-2.3.9.2).

997-2.3.9.6 Side Blocks. After the ship has landed all along the keel, the side blocks shall be hauled (if not already set in position prior to docking). The exact time shall be determined by stability calculations using equations (2-11) and (2-12) of paragraph 997-2.5.4.3.4. The side blocks must be in place before the ship reaches the draft at instability (i.e., the draft at which its virtual metacentric height is equal to zero (see Figure 997-A-2).

997-2.3.9.7 Gangways and Service Lines. Installation of gangways and service lines shall be deferred until after the ship has landed and side blocks are in position. If a gangway is needed promptly, it may be suspended by a crane during the pumping down or raising operations. Service lines shall be promptly installed after the ship has landed and side blocks are in position.

997-2.3.9.8 Electrical Grounding. As soon as possible, after the ship has landed and side blocks are in position, a grounding cable or grounding strap shall be attached between the ship and dock to protect the ship from the effects of electric storms and welding.

997-2.3.10 EXAMINATION OF BLOCKS. The Docking Officer (in naval facilities) or SUPSHIP Representative and the contractor's Dockmaster (in commercial facilities) shall remain at the floating or graving dock until the dock is pumped out sufficiently to permit personal examination of all blocks. Any irregularities found shall be corrected and any necessary shoring shall be placed before the Docking Officer or SUPSHIP Representative and the contractor's Dockmaster leave the dock. Similarly, the Docking Officer or SUPSHIP Representative and the contractor's Dockmaster shall remain at the vertical lift facility until the facility is raised sufficiently to permit personal examination of all blocks and correction of any irregularities found. In all such cases, the docking crew shall likewise remain at the facility to assist as needed.

997-2.4 ACTION AFTER DOCKING

997-2.4.1 CORRECTIONS TO DOCKING DRAWING. If the docking drawing is found to be incorrect, or if modifications are made to the ship that in any way affect the docking of the ship, corrective actions shall be taken as detailed in the following paragraphs.

997-2.4.1.1 Docking at a Naval Shipyard. When a ship is docked at a naval shipyard, it is the responsibility of the shipyard to obtain the original docking drawing from the planning yard for modification. After the original drawing has been modified, a blueprint or vandyke of the drawing shall be distributed in accordance with docking drawing distribution list, Appendix H, Table 997-H-1, and the original returned to the planning yard for retention. The planning yard may, at its discretion, provide the shipyard with a reproducible copy of the docking drawing, in lieu of the original, to be marked up and returned. The planning yard will then correct the original in accordance with the marked-up copy and make distribution as above.

997-2.4.1.2 Docking at Other Than a Naval Shipyard. When a ship is docked at a naval facility other than a naval shipyard, or in a private shipyard, it is the responsibility of the Commanding Officer or Officer-in-Charge of the naval facility (or SUPSHIP Representative, for ships docked in private shipyards under whose cognizance the work is being accomplished) to ensure that adequate information concerning the modifications is forwarded to the appropriate planning yard. The planning yard shall make the necessary modifications to the docking drawing and distribute copies in accordance with docking drawing distribution list,Appendix H, Table 997-H-1.

997-2.4.1.3 Interim Action. Pending development of the modified docking drawing, the Docking Officer or SUPSHIP Representative shall furnish a dated marked-up copy of the docking drawing, with the docking report, to the ship's Commanding Officer prior to departure of the ship. This procedure will preclude the possibility of damage during subsequent dockings made prior to receipt of the corrected docking drawing.

997-2.4.2 MONITORING OF WEIGHT CHANGES. The Manager (or persons responsible for weights in a commercial shipyard) of the ship overhaul shall report all work accomplished to the Naval Architecture Weight Section of a naval shipyard or to the persons responsible for weights in a commercial shipyard. The Weight Section (or persons responsible for weights in a commercial shipyard), as a supplemental function to their weight report, shall keep accurate Condition A records of the ship during this period of drydocking and shall check draft marks for accuracy. For work accomplished in a commercial shipyard, the SUPSHIP Representative shall receive weight information. Further weight change considerations are provided in paragraph 997-5.2.2.3.

997-2.5 CALCULATION PROCEDURES AND TECHNICAL CONSIDERATIONS

997-2.5.1 SEISMIC AND HURRICANE CONSIDERATIONS. Seismic and hurricane forces shall be taken into consideration as follows.

a. The Docking Officer or the contractor's Dockmaster shall inspect and verify that adequate shoring or other means of ensuring the stability of side blocking is installed to resist possible earthquake (seismic) or hurricane forces if the dry dock is located in an area subject to such disturbances. Necessary measures for resisting earthquakes shall be routinely applied in docking nuclear and non-nuclear powered ships in seismic areas for all types of drydocking facilities, including floating dry docks. These earthquake-resisting measures shall be routinely applied in docking all nuclear powered ships (except CVN) regardless of dock location (seismic and non-seismic areas), including floating dry docks. Measures required to resist hurricane forces shall be undertaken when it appears advisable because of past experience at that time of year, weather reports, or storm warnings.

b. The main effect of either an earthquake or a hurricane is the development of an overturning moment (M) which could cause the side blocks to be overloaded and could result in rolling the docked ship off the docking blocks.

997-2.5.1.1 Estimating Overturning Moments. Examples are given in appendix G for estimating both seismic and hurricane overturning moments. In these examples, the overturning moment due to hurricane forces is about 56 percent of that due to seismic forces for the particular ship used (FF 1052). This factor is not constant, being dependent upon the configuration of the ship and the location of the center of gravity.

997-2.5.1.1.1 Seismic Overturning Moment. The seismic overturning moment (M_s) on a drydocked ship may be approximated by the following equation:

$M_s = (\Delta/g)\ (a)\ (KG)\ (2240)$ ft - lb (2 - 1)

where

Δ = displacement (tons) (NOTE: All tons in this document refer to long tons, which equal 2240 lb)

g = acceleration of gravity (32.2 ft/sec^2)

KG = distance from baseline to center of gravity of ship when waterborne (ft)

a = effective maximum horizontal earthquake acceleration imparted to ship (ft/sec^2).

The value of a has been taken as 0.2 times the acceleration of gravity (0.2g's). This acceleration, although higher than that generally assumed for buildings in seismic areas, is not believed to be excessive for the ship-block system, because of the possibility of far lower vibratory damping than in the case of buildings. With this assumption, equation (1) becomes:

$M_s = (.20)\ (\Delta)\ (KG)\ (2240)$

$= (448)\ (\Delta)\ (KG)$ ft-lb

Methods for determining KG are described in paragraph 997-2.5.4.2.

997-2.5.1.1.2 Hurricane Overturning Moment. The hurricane overturning moment (M_h) on a drydocked ship may be approximated by the following equation:

$M_h = A(KG_A)(0.004)(V)^2$ ft-lb (2 - 2)

where

A = sail (side) area of ship (ft^2)

KG_A = height of center of sail area above keel (ft)

V = velocity of wind (knots).

Note that this expression assumes that there is no shielding effect by the raised wing walls of the dry dock. This results in a conservative figure for M_h if such shielding does exist.

Note that there is no shielding effect when a ship is removed from a vertical lift platform and transported to a land position.

997-2.5.1.2 Resisting Overturning Moments. Three methods that may be used to resist the overturning moment are: stable side blocks, spur shores with side blocks, and wale shores with side blocks (see Figure 997-2-1). The use of stable side blocks is considered to be the most desirable of the three methods.

997-2.5.1.2.1 Side Blocks. There are two main considerations in side blocking to resist overturning moments:

a. The maximum crushing strength of the side blocks shall not be exceeded.

b. The side blocks must be stable. Transverse stability of the side blocks can be ensured by keeping the line of action of the side block within the middle one-third of the block. In some cases this will require the use of double pier blocks for each upper side block (as shown in Figure 997-2-1) for seismic forces. Similar conditions exist for hurricane forces.

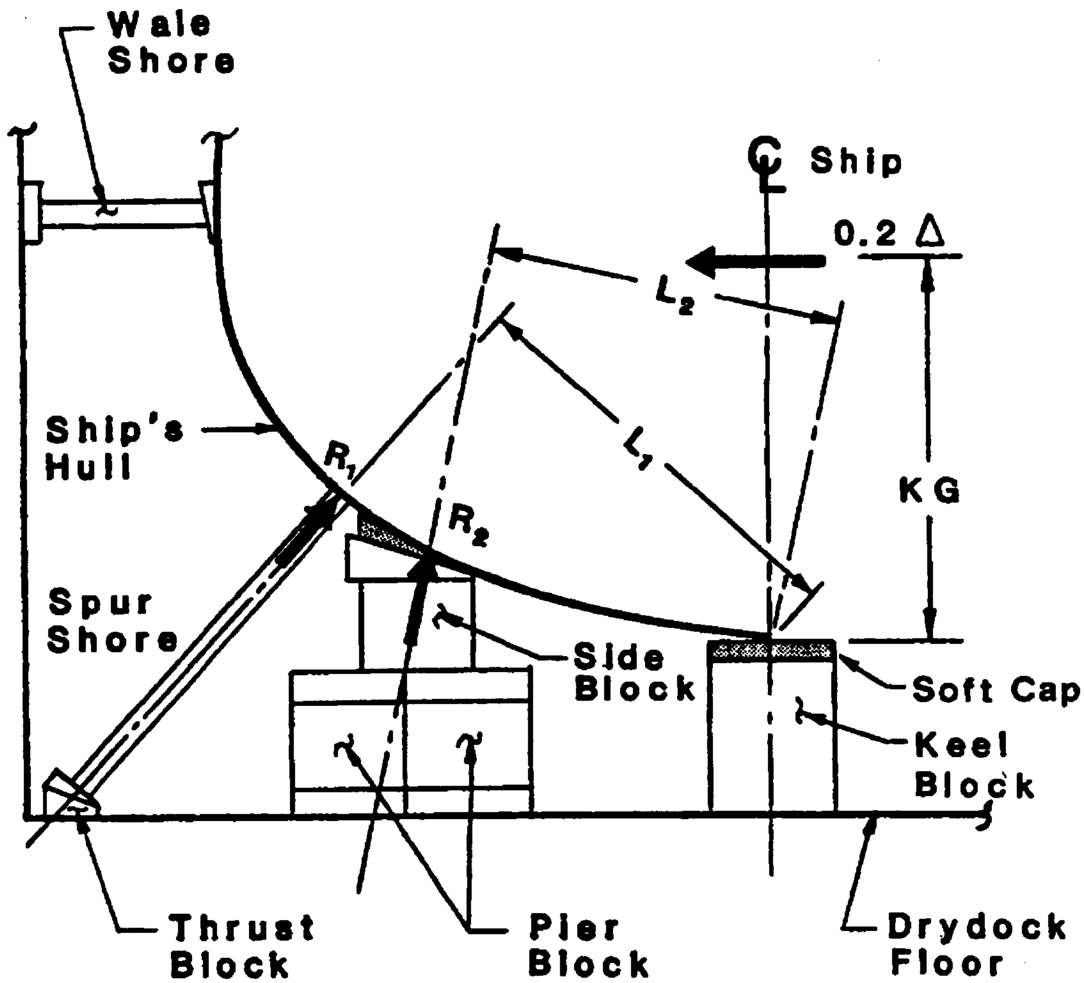


Figure 997-2-1. Computing Average Shore/Side Block Reaction To Ensure Transverse Stability in Dry Dock (Under Seismic Loading:Similar Conditions Exist for Hurricane Forces)

The proper number of side blocks may be determined by the following formula, assuming that the side blocks on only one side are effective:

$N_2 = M / (A_2 S_p L_2)$ (2 - 3)

where

N_2 = number of side blocks required on each side of the ship

M = overturning moment (ft-lb) = M_s or M_h (whichever is greater)

A_2 = effective contact area between the side blocks and the ship's hull (in^2)

S_p = strength proportional limit of block material (lb/in^2)

L_2 = average moment arm of side block reaction (ft) (see Figure 997-2-1).

NOTE

The number of side blocks required may be reduced by increasing the effective area of contact. This may be effected either by using fitted side blocks or by increasing the fore-and-aft length of universal cap blocks. Numerical examples of side blocking for seismic and hurricane forces are given in appendix G.

997-2.5.1.3 Side Blocks and Shores. Shoring and sideblocking may be combined to resist overturning moments. The spur shores will fail as columns before they will fail in direct compression. To test the column stability of the shore-side block system, the following two equations may be used to determine the average reaction at the shores, R_1 , and at the side blocks, R_2 :

$$R_1 = M\left(\frac{K_1L_1}{L_1{}^2N_1K_1 + L_2{}^2N_2K_2}\right) \qquad (2-4)$$

$$R_2 = M\left(\frac{K_2L_2}{L_1{}^2N_1K_1 + L_2{}^2N_2K_2}\right) \qquad (2-5)$$

where

M = overturning moment (ft-lb) = M_2 or M_h (whichever is greater)

L_1 = average moment arm of spur shores' reactions (ft) (see Figure 997-2-1)

L_2 = average moment arm of side block reaction (ft) (see Figure 997-2-1)

N_1 = number of spur shores required on each side of ship

N_2 = number of side blocks required on each side of ship

K_1 = spring constant of spur shore (lbs/in)

K_2 = spring constant of side block (lbs/in)

R_1 = average shore reaction (lb)

R_2 = average side block reaction (lb).

An estimate is first made of the number of shores and side blocks required, the R_1 is calculated and the shores checked individually for column stability. In no case shall the number of side blocks used be less than would be required for safe docking, not considering seismic or hurricane forces.

Thrust blocks shall be provided at the base of all spur shores. The thrust blocks shall be firmly secured to sockets in the dock floor or anchored in some other satisfactory manner. A numerical example of the use of spur shores in conjunction with side blocks is given in appendix G.

Concerning wale shores (shore fitted between the ship hull at the gunwale and the dock wall), several points should be borne in mind. The wale shores must be suitably secured to prevent the shores on one side from falling out when those on the opposite side are compressed. Wale shores are not well suited to dockings in which there is considerable clearance between the ship and dock wall, as the excessive length of the shores would require either a large number of wale shores or shores so heavy as to make them unwieldy.

The large number of shores required to ensure their stability as columns decreases the natural period of the ship-keel block system, more closely approaching the periods of the stronger components of severe earthquakes. Should accelerations greater than 0.2g cause failure of the shores as columns, the ship would have insufficient lateral support to resist the lesser forces of the longer period seismic motions, due to the reduction in number of side blocks achieved through use of shores. Also, both wale shores and spur shores create interferences with dock work not imposed by side blocks. For the preceding reasons, the use of stable side blocks is recommended unless special circumstances or shipyard practice indicate the use of shores as being preferable.

997-2.5.2 ALLOWABLE STRESSES. The following paragraphs deal with block loading stresses in general (Trim-generated loads are considered in detail in paragraph 997-2.5.5).

997-2.5.2.1 Stress-Strain Characteristics of Docking Blocks. Historically, stress-strain characteristics of docking blocks did not represent a critical element in drydocking. Ships traditionally had thick hulls and wide, flat bottoms with full-length keels and short bow and stern overhangs. Drydock blocks could easily bear the resulting loading of 150-300 lb/in^2 . More recently, the hulls have become thinner and narrower, as have the keels, and large bow and stern overhangs are common features in today's combatants. As a result, block loading has increased in magnitude and block stress-strain characteristics now must be considered in some detail.

The timber of docking blocks is loaded perpendicular to the grain; in almost all other structural applications, wood is loaded parallel to the grain (where it is much stronger). Thus, very little stress-strain data has existed for wood loaded perpendicular to the grain, especially for full sized docking block timber or complete docking blocks. Recently a series of full size tests has been run. These full size tests produced an accurate understanding of stress-strain characteristics of docking blocks and the test results are considered in the following paragraphs.

997-2.5.2.2 Safe Allowable Timber Stress. For the purpose of keel docking blocks, the safe allowable timber compressive stress for distributed loading, taken as the fiber stress at the proportional limit of Douglas fir, is 370 lb/in^2 . This assumes a uniform pressure over the entire 42 by 48 inch top of a docking block, resulting in a total load of approximately 330 tons. (Side block distributed loading is discussed in appendix G and is based on a different criterion).

997-2.5.2.3 Effect of Narrow Skeg or Keel. The athwartship dimension of the standard docking block is 4 feet. The skegs or keels of most ships are narrower than this and in some cases much narrower. When the bearing width of the keel is as much as three-quarters of the block width, the problem of stress concentration immediately under the keel is not a serious one. In such cases the permissible total knuckle reaction is controlled by maximum allowable stress at the after end of the knuckle block, considering the entire width of the blocks, and also by maximum total load on the last block; however, when the keel or skeg width is less than about 3 feet, the knuckle stresses (considering the entire width of the block) should be reduced to allow for appreciable stress concentration under the keel. Some examples will clarify this. For ships with a 3-foot keel width at the knuckle, the maximum stress at the after end of the knuckle block has been limited to 370 lb/in^2 . The corresponding total load on the last block is just under 330 tons. For heavy and light cruisers, with skeg widths of 2 feet, the maximum allowable stress at the aft end of the knuckle block has been reduced to 227 lb/in^2 . The stress immediately under the two-foot skeg will be twice this, or approximately 550 lb/in^2 . For ships with a skeg width of 1 foot, the allowable knuckle stress has been further reduced to about 184 lb/in^2 The stress concentration will be four times this, but the concentration is of such limited extent and the duration of maximum stress is so brief that this figure is believed to be satisfactory even for soft caps; however, it is considered advisable to use hardwood capping at the knuckle when docking ships with keels or skegs appreciably narrower than the docking blocks, because the hardwood will be able to carry stress concentrations which would cause severe crushing of soft capping. For soft caps, an additional compression is considered in determining the stress in the knuckle block (see appendix F). Hard caps should be used in conjunction with a soft wood stratum below, to give the same overall compressive characteristics to the block. For certain tugs and other ships having bar keels, the use of caps bound with steel angles will prevent the bar keel from cutting into the caps. Example values of knuckle block compression and allowable stress are shown in Table 997-2-1.

997-2.5.2.4 Reuse of Blocking Soft Caps. A soft cap may be reused if the crushed portion is removed and (following the removal) the cap is still at least 2 inches thick. Prior to the reuse of any soft wood cap, prudent judgment must be exercised to ensure that, after the removal of the crushed portion of the block, the remaining portion is of good material condition and is free of other defects such as splitting, warping, end checking, excessive damage from dogging, and interior decay.

997-2.5.3 HIGH DOCKING BLOCK STABILITY. The installation of large sonar domes on anti-submarine warfare ships necessitates docking these ships on high blocks. Occasionally, additional ship classes are also docked on high blocks. Drydocking ships on high blocks results in problems in ensuring the column stability of the individual blocks and the stability of the blocking system.

a. Blocks in excess of 6 feet in height but below 8 feet 6 inches in height shall be considered high blocks. Blocks which are 8 feet 6 inches or greater in height shall be considered extra-high blocks.

b. High keel blocks shall be cribbed or butted in the aft one-third and forward one-third of the keel block line. All extra-high keel blocks shall be cribbed or butted.

c. Side blocks above 6 feet in height (measured from the bottom of the block to the highest corner of the soft cap) shall be tied together longitudinally in pairs by means of steel bracing, or joined by cribbing, or be constructed as individual pyramids. If the side blocks are haul blocks, they must be hauled in pairs.

d. Guidance for high block builds is provided on the following drawings. Docking blocks for graving docks are indicated on Naval Facilities Engineering Command (NAVFAC) Drawing 817336 for wood blocks and NAVFAC Drawings 822374 and 900496 for composite wood and concrete blocks. High blocks for floating dry docks ARDM, AFDM and ARD are indicated on NAVFAC Drawings 797762 and 789241. High blocks for vertical lift facilities, such as the Syncrolift, may be the same as those for floating dry docks indicated on NAVFAC Drawings 797762 and 789241. Alternative side blocks for AFDM floating dry docks are indicated on Naval Ship Systems Command (NAVSHIPSYSCOM) Drawing 4598603.

Table 997-2-1. KNUCKLE BLOCK COMPRESSION AND ALLOWABLE STRESS

Keel Width, ft	Compression of Knuckle Block (C_{KN}), in	Allowable Unit Stress at Aft End of Knuckle Block (S), lb/in^2
≥3.00	.38	370
2.50	.34	323
2.00	.30	277
1.75	.28	254
1.50	.26	230
1.25	.25	207
1.00	.23	184

997-2.5.4 TRANSVERSE STABILITY CONSIDERATIONS. Consideration must be given to the stability of a ship while the water is being pumped out of the dry dock, or with vertical lift facilities prior to initiation and during conductance of the lifting operations, particularly if the ship has appreciable trim. (Stability of a floating dry dock, empty and with a ship docked inside, must also be considered. This topic is fully addressed in MIL-STD-1625, Safety Certification Program for Drydocking Facilities and Shipbuilding Ways for U.S. Navy Ships .)

997-2.5.4.1 The Potential for Instability. The reaction of the docking blocks on a ship amounts to removing weight from the ship's keel. The reaction on the docking blocks at any time during pumping down or lifting operations is equal to the difference in displacement at the floating draft and the displacement at the waterline under consideration in the landed condition. The effect of keel block reaction is a virtual rise in the center of gravity. The keel blocks are assumed to be knife edge supports and offer no resistance to overturning.

Referring to Figure 997-2-2:

$KG_v = (\Delta\ KG) / (\Delta - R_{KN})$ (2 - 6)

$GG_v = KG_v - KG = [\ (\Delta\ KG) / (\Delta - R_{KN})\ ] - KG$

or

$GG_v = (\ (KG)(R_{KN})\ ) / (\Delta - R_{KN})$ (2 - 7)

where

KG_v = virtual height of center of gravity above keel (ft)

KG = height of center of gravity of ship above keel when waterborne (ft)

GG_v = virtual rise in center of gravity (ft)

Δ = displacement of ship (waterborne) (tons)

R_{KN} = keel block reaction due to the difference in displacement between the waterborne draft and the landing draft (tons)

$(\Delta - R_{KN})$ = the residual buoyancy (tons).

As the dry dock is being pumped down, or the vertical lift is being raised, the keel block reaction is being increased. The vertical center of gravity will eventually rise to a position where the metacentric height at waterline $W_1\ L_1$, $G_v\ M_1$ (virtual metacentric height of the new waterline, $W_1\ L_1$ Figure 997-2-2), and the righting arm for small angles of heel will become zero. The ship's draft at this condition of zero $G_v\ M_1$, is called the draft at instability . Note that if the draft at instability is reached before the ship has landed fore and aft on the keel blocks, then the ship becomes unstable during the docking evolution. On the other hand, if the draft at instability is not reached until well after the ship has landed fore and aft, then the ship remains stable throughout the docking evolution. Thus, the observation can be made: if the draft at instability is much lower than the draft at landing fore and aft, the ship will dock safely . For example, if the draft at instability is 13 feet and the draft at landing is 15 feet, then the ship will remain stable during docking. This subject is discussed in further detail in the following paragraphs.

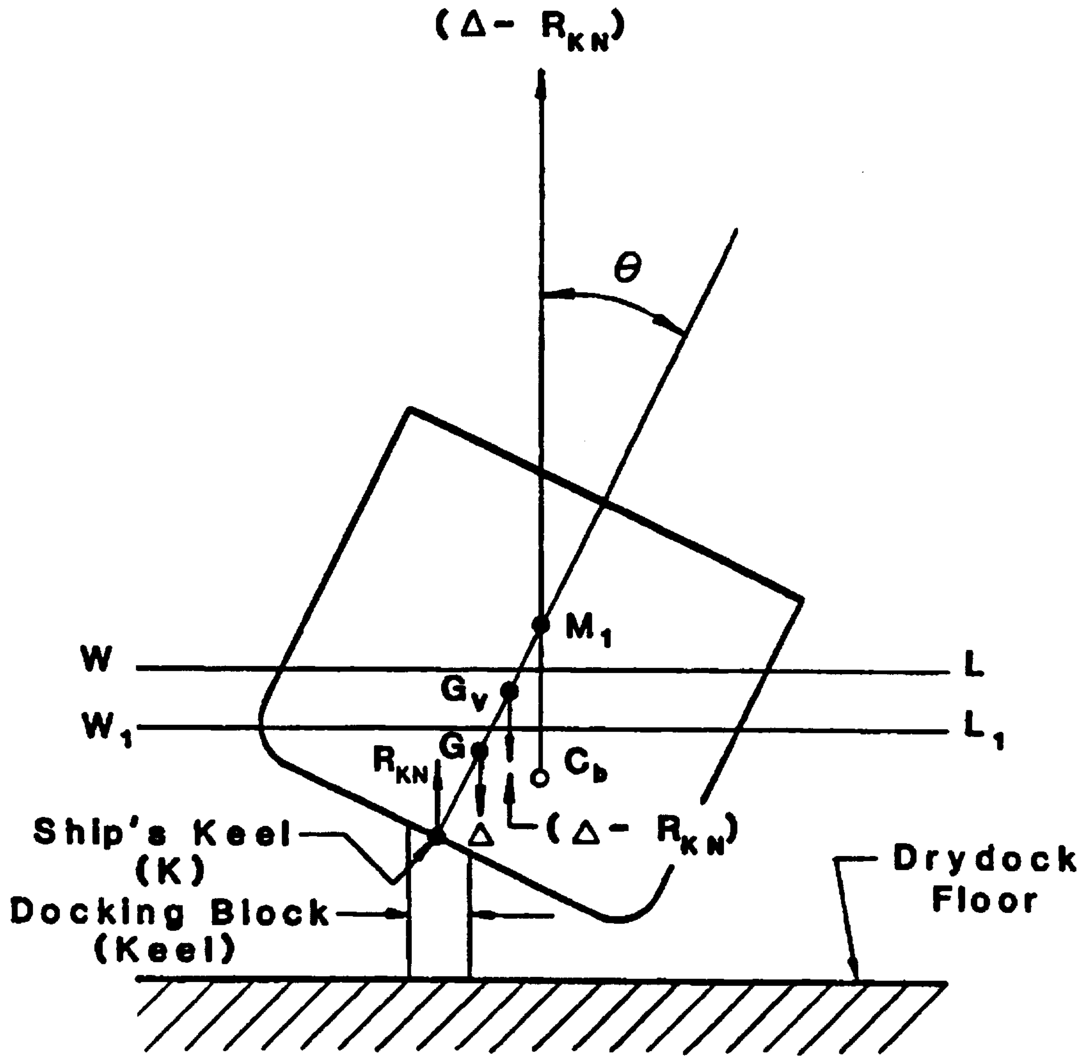


Figure 997-2-2. Computing Virtual Rise in Center of Gravity During Drydock Pumpdown

997-2.5.4.2 Determining GM and KG. The following paragraphs provide approximate methods for finding GM, and thus the location of the vertical center of gravity, KG, which may be used in calculating draft at instability.

997-2.5.4.2.1 Existing Documentation. Inclining experiments or stability and loading data are contained in damage control books. An inclining experiment for the ship contains information on stability characteristics for different conditions of loading. In some experiments, the GM or KG values for light ship condition only are given. A weight and vertical moment study of the ship's loading shall be made prior to drydocking to determine the GM or KG value. Inclining experiment data for other ships in the same class may be used if such is not available for the ship to be docked.

997-2.5.4.2.2 Developing an Estimate When Documentation Not Available. If no stability data are available, the GM or KG value may be roughly approximated by sallying (rolling) the ship. The ship may be sallied by running personnel across the beam of the ship or by lifting weights up and down on the deck with a crane. The roll should be developed to such an extent that several cycles of measurable roll will occur before damping moments destroy the motion. Using the average time for a period of roll, T, in seconds (a period of roll is the time required for a ship to roll from a maximum on one side to a maximum on the other and back), the GM value may be calculated using the following roll formula:

$GM = (C_c{}^2 B^2) / T^2$ (2 - 8)

where

C_c = a constant (sample values are given in Table 997-2-2

B = beam of ship (ft)

T = period of roll for one complete cycle, from a maximum on one side to a maximum on the other and back (sec).

Thus, from the value of GM, the value of KG may be obtained from the relation:

KG = KM - GM

where

KG = height of center of gravity of ship above keel when waterborne (ft)

KM = height of metacenter above the ship's keel (ft)

GM = metacentric height (ft).

The value of KM is obtainable from the curves of form. It is emphasized that the C_c value is only an approximation and enters the equation as the square of its value. The GM value thus obtained is, therefore, an approximation.

Table 997-2-2. SAMPLE C_c VALUES

SHIP TYPES	**C_c**
Auxiliaries	0.44
Aircraft Carriers	0.58
Cruisers	0.43
DD692 (short hull)	0.42
Destroyers (other)	0.44
Destroyer Escorts	0.45
Landing Ships	0.46
Patrol Craft	0.47
Submarines	
Body of Revolution hull	0.41
Other (fleet type)	0.36
Tugs	0.40

997-2.5.4.3 Determining Draft at Landing and Draft at Instability. The following paragraphs present methods to calculate the draft at landing and the draft at instability.

997-2.5.4.3.1 Calculating Draft at Landing, Exact Method. During pumping down or raising of the docking facility, a ship with a trim by the stern lands on the aftermost or knuckle block and then pivots about this point. The ship will continue to pivot until landing fore-and-aft. The ship will land fore-and-aft when the residual buoyancy moment equals the weight moment, with moments taken about the centroid of the force on the aft end of the knuckle block. The draft at which this occurs may be calculated as follows:

1. Determine the displacement, longitudinal center of gravity, and longitudinal center of buoyancy of the fully waterborne ship.
2. Calculate (or obtain from the curves of form) the longitudinal center of buoyancy (LCB) and the residual buoyancy at waterlines below floating drafts parallel to the inclination of the floating dry dock.

NOTE

For most dry docks these waterlines will be horizontal. Since the ship will pivot while water is being pumped out, or the docking facility is being raised, the LCB and residual buoyancy figures will not be theoretically correct for a ship with a trim. However, the figures will be sufficiently accurate for this purpose since the limiting condition will occur when the ship just lands fore-and-aft.

3. Calculate moments of residual buoyancy and weight about the aft end of the knuckle block for the different waterlines involved.

NOTE

The resultant of the keel block reaction while trimming down acts at a point increasingly forward of the knuckle block. The shift forward will oppose the landing of the bow and result in deeper draft at landing than if this reaction were neglected. In most cases, however, the effective location of the keel reaction is only about five percent of the length of the keel block system forward of the aft end of the knuckle block when the ship has landed. Therefore, the change in the location of the moment about the aft end of the knuckle block is small in most cases and can be neglected due to its negligible effect on the draft at landing. However, if the stability while landing is critical, calculations should be made to include the forward shift of the keel reaction by taking moments further forward, meaning at the centroid of the keel reaction. Conservative stability assumptions, recommended for general use, are that the effective location of keel reaction is five percent of the length of the keel block system forward of the aft end of the knuckle block.

4. Using graph paper, plot waterlines of drafts as ordinates and moments as abscissae.
5. Since the weight moment will not vary due to draft, the weight moment curve will be a straight vertical line on the graph. The plot of residual buoyancy (moment) may be slightly curved. The point at which these two lines intersect will give the draft at landing fore-and-aft.

See numerical example, Appendix A.

997-2.5.4.3.2 Calculating Draft at Landing, Approximation. The following equations provide an approximate method for finding draft at landing.
R_{KN} = t(MT1″) / kX_{KN} (2 - 9)
where

t = total trim (inches, not feet, in this case)

MT1″ = moment to trim 1 inch (ft-tons/in)

k = constant (.97, for ships with small stern overhang, .94 for ships with large stern overhang)

X_{KN} = distance from aft end of knuckle block to longitudinal center of flotation (LCF) (ft)

and
$H_1 = Hm - (R_{KN} / (12\ TP1''))$ (2 - 10)
where

H_1 = mean draft at landing (ft)

H_m = mean draft of waterborne ship (ft)

TP1″ = tons per one inch immersion at the mean draft.

997-2.5.4.3.3 Calculating Draft at Landing, Rule of Thumb. A rule of thumb method to find the draft at landing is:

$H_1 = H_D - (2/3)(H_A - H_F)$

where

H_D = deep draft (ft), which is the larger of the two drafts (H_F , H_A), in this case H_A

H_F = forward draft (ft)

H_A = aft draft (ft).

NOTE

If there is any doubt of the stability of the ship during docking, use the more accurate method in paragraph 997-2.5.4.3.1.

997-2.5.4.3.4 Calculating Draft at Instability. The limit of stability (or ″draft at instability″) occurs at a draft when the virtual metacentric height, $G_v M_1$, equals zero. Since
$G_v M_1 = KM_1 - KG_v = KM_1 - [(\Delta\ KG)/(\Delta - R_{KN})]$ (2 - 11)
where

G_v = that point which describes the virtual center of gravity of the ship at the waterline $W_1 L_1$

M_1 = metacenter at the waterline $W_1 L_1$ (ft) (see Figure 997-2-2)

KG_v = virtual height of center of gravity above keel (ft)

Δ = displacement of ship (waterborne) (tons)

KG = height of center of gravity of ship above keel when waterborne (ft)

R_{KN} = keel block reaction (tons)

KM_1 = height of metacenter above the ship's keel at instability (ft)

when: $G_v M_1 = 0$,
then: $KM_1 (\Delta - R_{KN}) = \Delta (KG)$. (2 - 12)

To find the draft at instability, obtain the height of the metacenter above the keel (KM_1) and the residual buoyancy ($\Delta - R_{KN}$) at different drafts below the floating draft. KG may be obtained from the inclining experiment (paragraph 997-2.5.4.2.1 or by sallying the ship (paragraph 997-2.5.4.2.2). On graph paper, with drafts as ordinates and moments as abscissa, plot $KM_1 (\Delta - R_{KN})$ versus draft and $\Delta(KG)$ versus draft. The (KG) (Δ) curve is a straight vertical line and the KM_1 (Δ - R_{KN}) plot is slightly curved. The point at which these two lines intersect will give the draft when G_v M_1 equals zero (see numerical example, Appendix A).

997-2.5.4.4 Acceptable Stability. Generally speaking, a ship has acceptable stability for drydocking if the ship's draft at instability is much lower than the draft at landing fore and aft.

997-2.5.4.4.1 If the difference between the draft at landing and the draft at instability is 1 foot or greater, then the ship has acceptable stability for landing on the keel blocks fore and aft and, subsequently, hauling the side blocks.

997-2.5.4.4.2 If the difference between the draft at landing and the draft at instability is less than one foot but equal to or greater than 6 inches, then prepositioned (prior to the ship landing fore and aft) side blocks are required for acceptable stability.

997-2.5.4.4.3 If the difference between the draft at landing and the draft at instability is less than 6 inches, then the ship does not have acceptable stability for drydocking.

997-2.5.4.5 Correcting a Ship's Instability. If calculations show that the ship will become unstable before landing fore-and-aft, action must be taken to remedy the situation. The first and most obvious remedy would be to remove the trim of a ship to conform to the profile of the docking blocks. A ship in this condition would land fore-and-aft at approximately the same time. Means to remove trim are discussed in paragraph 997-2.5.5.1. If the trim cannot be altered to conform to the profile of the docking blocks, the vertical center of gravity of the ship must be lowered to improve GM, the metacentric height. This may be accomplished by the addition, removal, or relocation of weights, or reduction of free surface on board the ship.

997-2.5.5 TRIM CONSIDERATIONS. A ship entering dry dock should be without excessive trim. Trim in excess of the allowable figure as discussed in paragraph 997-2.5.5.2.3 may make the docking operation hazardous. If examination of the ship by the docking activity's representatives is not possible before docking, the Commanding Officer of the ship shall inform the activity of the draft forward and the draft aft, in reference to the keel, and the amount of list. This information shall be furnished sufficiently in advance of the time of docking to permit safe docking arrangements to be made without delaying the docking.

997-2.5.5.1 Reducing a Ship's Trim. It is frequently necessary to reduce a ship's trim prior to entering dry dock. This can usually be accomplished by transfer of liquids in inner bottom or wing tanks, or in some instances by shifting weights or cargo aboard the ship.

997-2.5.5.1.1 If the ship is small, it may be trimmed by placing small trimming weights on the deck. In docking a ship with a bow-mounted sonar dome, it may be advantageous to dewater the dome, resulting usually in a trim by the stern, which may be corrected (or at least reduced) by transferring liquid ballast forward. If the dome is dewatered, the docking instructions for bow-mounted sonar domes shall be followed. These instructions are placed on the docking drawings of ships with sonar domes, and concern the safety of the domes.

997-2.5.5.1.2 The addition of trimming weights will also raise the vertical center of gravity and decrease the metacentric height (GM), resulting in decreased stability. For example, this is especially true for the FFG 1 and FF 1040 class ships.

997-2.5.5.2 Docking Block Loading. The following paragraphs discuss subjects relative to drydock blocks from the perspective of trim-induced loading.

997-2.5.5.2.1 Determining Block Loads. Methods for determining total knuckle reaction, individual block loads, and maximum unit stresses during the trimming-out process are discussed in appendices B, C, and D. As shown in the following paragraphs, easily applied formulas for maximum allowable trim have been developed, both for butted and spaced blocks, and permissible constants for the formulas have been derived for representative classes of combat ships and naval auxiliaries.

997-2.5.5.2.2 Block Composition. The treatment of block loads and stresses has been made with particular reference to typical composite dock blocks, that is, blocks consisting of a lower stratum of concrete, an upper stratum of hardwood, and finally a cap piece of either soft or hardwood. While the methods discussed can be applied to an all-timber block, it must be emphasized that the constants for the allowable trim formulas (equations 2-13 and 2-16) will not be applicable in this case. For all-timber blocks, new constants may be calculated using the information in Appendix E and a suitable stress-deflection curve for the all-timber blocks.

997-2.5.5.2.3 Allowable Trim. In this context, allowable trim is the maximum trim which the ship can have at docking and still be within the safe stress limits of the knuckle block. Equations 2-13 and 2-16 have been used to calculate the allowable trim values, which are provided in Table 997-2-3. This table may be used as a guide to safe allowable trim while docking. All the pertinent data involved in the allowable trim calculations for various classes of ships are summarized in this table. These data include S, C_{KN} , L, X_{KN} MT1″, displacement, draft, C values, and so forth. In a horizontal direction, this table gives the data relating to any one class of ship, so a comparison of allowable trim (full load condition and light ship) for both butted and spaced blocks may be made. In a vertical direction, any one column of the table makes it possible to compare any specific factor for all the classes of ships.

997-2.5.5.2.3.1 It should be emphasized that Table 997-2-3 must be used with judgment, especially for ships other than those listed and for blocks with characteristics markedly different from those assumed. The equations, from which the portions of Table 997-2-3 dealing with spaced blocks have been computed, are set up specifically for blocks measuring 42 inches fore-and-aft, spaced 6 feet center to center. For any block arrangement differing appreciably from this, new equations should be derived from the information in Appendix E . Examples of the calculations to find the maximum trim are given in Appendix E . Furthermore, these values of allowable trim presuppose adequate transverse stability of the ship. Also, the following should be kept in mind when using this table:

a. The table is an example only. While it provides the maximum allowable trim for ships in the two envelope conditions, full load and light ship, it does not furnish any data for conditions between those two extremes. Therefore, allowable trim calculations will have to be conducted for every ship, based on the ship's condition at the time of drydocking.

b. The trim values provided for SSN/SSBNs are provided for completeness only, since nuclear submarines are normally docked without any appreciable trim.

c. For MSC, MSO and YTB classes, the knuckle pressure imposes no restriction on the amount of trim; therefore, these classes are omitted from the table.

d. This table and the related equations are concerned only with short duration knuckle loads while a ship with trim is pivoting down onto the blocks. When large ships with long overhangs, such as aircraft carriers, are docked on blocks with soft caps, severe crushing will occur after the dock is pumped dry. In such cases, hard caps near the knuckle are desirable.

997-2.5.5.2.3.2 In the following subsections, equations for calculating allowable trim are presented. These equations are derived in Appendix E .

a. Butted Blocks. The formula for allowable trim with butted blocks is:
$t_a = C \sqrt{(X_{KN} / MT1'')}$ (2 - 13)
where

t_a = Allowable trim between perpendiculars (ft) (for most ships this is essentially the trim between draft marks)

C = A constant for a specific hull and type of block ($(ft^2$ -tons)/in)

X_{KN} = Distance from knuckle block to longitudinal center of flotation (ft)

MT1″ = Moment to trim one inch ((ft-tons)/in)

Table 997-2-3 ALLOWABLE TRIM DURING DOCKING

							FULL LOAD CONDITION				LIGHT SHIP CONDITION				
SHIP	**L (ft)**	**OVER-HANG (KNUCKLE TO AP) (ft)**	**OVER-HANG (KNUCKLE TO AP) AS % OF L**	**KEEL WIDTH AT KNUCKLE (ft)**	**Ckn (in)**	**S MAX ALLOWABLE STRESS IN BLOCK (psi)**	**KNUC TO LCF Xkn (ft)**	**NT1″ (ft-tons)**	**MEAN DRAFT (ft)**	**DIS-PLACEMENT (tons)**	**KNUC TO LCF Xkn (ft)**	**MT1″ (ft-tons)**	**MEAN DRAFT (ft)**	**DIS-PLACEMENT (tons)**	**SHIP TYPE TABLE 2.4**
AD-15	520.0	48.2	9.3	2.0	0.30	277	198.8	1810	23.0	15980	208.3	1560	16.0	10500	1
AD-37	620.0	75.8	12.2	4.0	0.38	370	207.3	3720	28.0	26480	217.7	2780	18.0	15120	1
AE-21	486.5	24.0	4.9	4.0	0.38	370	206.0	1588	29.0	17450	219.9	1093	17.0	9300	1
AE-23	486.6	25.9	5.3	4.0	0.38	370	204.0	1588	29.0	17450	217.9	1093	17.0	9300	1
AE-26	539.6	89.7	16.6	4.0	0.38	370	154.2	2392	28.0	20270	175.5	1539	18.0	11450	1
AFS-1	530.0	18.5	3.5	4.0	0.38	370	229.2	1971	26.0	17800	242.7	1490	17.0	10500	1
AOE-1	770.0	110.0	14.3	2.0	0.30	277	227.3	6235	40.0	55100	272.0	3700	20.0	23350	1
AOR-1	638.8	13.0	2.0	2.0	0.30	277	233.3	3960	34.0	38560	260.3	2530	16.0	15870	1
AO-177	550.0	40.0	7.3	2.0	0.30	277	209.9	2690	36.0	30988	237.3	1585	11.0	7666	1
AO-98	616.0	6.0	1.0	2.0	0.30	277	282.8	3550	37.0	37020	306.3	2630	13.0	11710	1
AR-5	520.0	52.7	10.1	2.0	0.30	277	194.5	1820	23.0	15975	205.3	1530	15.0	9740	1
AS-11	520.0	52.0	10.0	4.0	0.38	370	212.0	1785	22.0	15180	219.0	1490	14.0	9000	1
AS-19	564.0	54.3	9.6	3.0	0.38	370	215.8	2238	22.0	17170	226.9	1886	14.0	10240	1
AS-31	570.0	60.0	10.5	4.0	0.38	370	205.1	2403	25.0	19145	214.5	1833	17.0	11740	1
AS-33	620.0	74.5	12.0	3.0	0.38	370	208.7	3720	28.0	26520	219.3	2780	18.0	15100	1
AS-36	620.0	79.8	12.9	4.0	0.38	370	202.6	3660	28.0	26450	215.3	2724	18.0	15000	1
AS-39	620.0	79.8	12.9	4.0	0.38	370	202.6	3660	28.0	26450	215.3	2724	18.0	15000	1
BB-61	860.0	69.8	8.1	4.0	0.38	370	287.1	6740	36.0	57170	295.5	6310	30.0	46200	5
CGN-09	689.4	130.4	18.9	3.0	0.38	370	263.0	3266	24.0	16810	173.7	2778	19.0	11750	2
CGN-25	539.2	95.9	17.8	2.0	0.30	277	133.1	1668	21.0	9280	134.5	1576	18.5	7650	2
CGN-35	540.0	96.0	17.8	2.0	0.30	277	138.0	1748	20.5	9220	138.7	1692	19.0	8215	2
CGN-36	570.0	111.0	19.5	2.0	0.30	277	136.9	2079	23.0	11880	137.6	1935	19.5	9325	2
CGN-38	560.0	93.3	16.7	2.0	0.30	277	148.0	2198	23.0	12380	147.4	2055	19.5	9700	2
CG-16	509.9	89.9	17.6	2.0	0.30	277	129.9	1371	20.0	8115	138.5	1121	14.0	4750	2
CG-26	523.7	99.1	18.9	2.0	0.30	277	128.2	1475	20.0	8605	137.4	1187	14.0	5113	2
CG-47	529.0	117.0	22.1	2.0	0.30	277	109.2	1240	16.0	5820	98.7	1600	22.0	9440	2
CVN-65	1040.2	142.0	13.7	8.0	0.38	370	319.5	14470	37.0	88200	324.8	12810	31.0	71270	5
CVN-68	1040.0	144.3	13.9	8.0	0.38	370	316.2	15320	38.0	95150	340.0	12210	28.0	65700	5
CV-41	900.0	140.4	15.6	8.0	0.38	370	274.1	9560	34.0	67260	297.3	7625	26.0	47770	3
CV-59	990.0	116.0	11.7	8.0	0.38	370	314.4	12770	36.0	78600	326.6	11340	31.0	65200	5

Table 997-2-3 ALLOWABLE TRIM DURING DOCKING - Continued

							FULL LOAD CONDITION				LIGHT SHIP CONDITION				
SHIP	**L (ft)**	**OVER-HANG (KNUCKLE TO AP) (ft)**	**OVER-HANG (KNUCKLE TO AP) AS % OF L**	**KEEL WIDTH AT KNUCKLE (ft)**	**Ckn (in)**	**S MAX ALLOWABLE STRESS IN BLOCK (psi)**	**KNUC TO LCF Xkn (ft)**	**NT1″ (ft-tons)**	**MEAN DRAFT (ft)**	**DIS-PLACEMENT (tons)**	**KNUC TO LCF Xkn (ft)**	**MT1″ (ft-tons)**	**MEAN DRAFT (ft)**	**DIS-PLACEMENT (tons)**	**SHIP TYPE TABLE 2.4**
CV-63	990.0	106.3	10.7	8.0	0.38	370	324.2	12770	36.0	78600	347.2	10260	28.0	57450	5
CV-67	990.0	132.0	13.3	8.0	0.38	370	305.6	13120	36.0	81250	324.9	10840	28.0	59700	5
DDG-2	420.0	72.0	17.1	1.5	0.26	230	116.1	938	17.0	5435	123.5	748	12.0	3320	1
DDG-40	490.0	89.0	18.2	2.0	0.30	277	125.8	1158	17.0	5428	133.7	849	12.0	3052	1
DDG-993	528.5	123.3	23.3	2.0	0.30	277	98.7	1613	22.0	9420	109.5	1240	16.0	5810	1
DD-963	529.0	123.3	23.3	2.0	0.30	277	98.3	1552	20.0	8200	109.5	1240	16.0	5810	1
FFG-1	390.0	72.1	18.5	1.5	0.26	230	95.8	635	14.0	3226	109.8	444	11.0	2243	1
FFG-7	407.8	72.3	17.7	1.5	0.26	230	109.1	737	14.0	3270	113.2	668	13.0	2900	1
FF-1037	350.0	62.5	17.9	1.0	0.23	184	81.3	478	14.0	2790	90.7	386	11.0	1920	1
FF-1040	390.0	72.1	18.5	1.5	0.26	230	109.8	635	14.0	3226	95.8	444	11.0	2243	1
FF-1053	415.0	79.8	19.2	1.5	0.26	230	100.5	830	16.0	4440	111.9	588	12.0	2871	1
FF-1098	389.9	71.7	18.4	1.5	0.26	230	95.8	635	14.0	3226	109.8	444	11.0	2252	1
LCC-19	579.8	190.0	32.8	1.5	0.26	230	67.3	2545	28.0	20480	83.9	1860	20.0	13000	1
LHA-1	777.6	173.3	22.3	1.5	0.26	230	159.8	8006	26.0	39230	179.5	6480	21.0	29700	1
LKA-112	528.0	28.1	5.3	1.5	0.26	230	224.8	1622	24.0	16360	230.6	1427	18.0	11730	1
LPD-1	500.0	40.2	8.0	4.0	0.38	370	174.2	2062	21.0	13980	200.0	1237	12.0	6810	1
LPD-4	548.0	40.2	7.3	2.0	0.30	277	198.4	2650	22.0	17070	233.5	1540	12.0	7990	1
LPH-2	556.0	44.2	7.9	2.0	0.30	277	213.5	1920	26.0	17810	226.5	1404	18.0	11200	4
LSD-37	539.8	40.2	7.4	2.0	0.30	277	191.3	2628	22.0	16800	219.7	1572	12.0	7850	1
LSD-41	580.0	65.5	11.3	1.5	0.26	230	184.3	3322	22.0	18649	203.8	2331	15.0	11219	1
LST-1179	500.0	52.0	10.4	1.5	0.26	230	169.0	1420	14.0	7300	179.8	1140	11.0	5360	1
SSBN-608	411.1	42.5	10.3	2.0	0.30	277	181.1	653	28.0	7090	176.5	896	25.0	6398	1
SSBN-616	425.2	42.5	10.0	2.0	0.30	277	188.4	679	28.0	7401	180.6	1160	22.0	5805	1

Table 997-2-3 ALLOWABLE TRIM DURING DOCKING - Continued

							FULL LOAD CONDITION				LIGHT SHIP CONDITION				
SHIP	**L (ft)**	**OVER-HANG (KNUCKLE TO AP) (ft)**	**OVER-HANG (KNUCKLE TO AP) AS % OF L**	**KEEL WIDTH AT KNUCKLE (ft)**	**Ckn (in)**	**S MAX ALLOWABLE STRESS IN BLOCK (psi)**	**KNUC TO LCF Xkn (ft)**	**NT1″ (ft-tons)**	**MEAN DRAFT (ft)**	**DIS-PLACEMENT (tons)**	**KNUC TO LCF Xkn (ft)**	**MT1″ (ft-tons)**	**MEAN DRAFT (ft)**	**DIS-PLACEMENT (tons)**	**SHIP TYPE TABLE 2.4**
SSBN-627	424.9	42.5	10.0	2.0	0.30	277	188.4	679	28.0	7396	180.6	1160	22.0	5798	1
SSBN-640	425.2	42.5	10.0	2.0	0.30	277	187.6	679	28.0	7399	180.6	1160	22.0	5801	1
SSBN-726	559.3	82.3	14.7	3.0	0.38	370	229.0	1030	38.0	17660	221.4	2084	32.0	15275	1
SSN-578	267.7	46.8	17.5	2.0	0.30	277	85.4	107	21.0	2596	79.6	248	18.0	2250	1
SSN-585	246.0	25.8	10.5	2.0	0.30	277	112.1	132	26.0	3197	105.7	267	22.0	2720	1
SSN-595	278.1	37.0	13.3	2.0	0.30	277	123.6	134	26.0	3858	115.1	210	22.0	3260	1
SSN-637	292.3	38.5	13.2	2.0	0.30	277	132.1	90	28.0	4527	126.0	279	22.0	3619	1
SSN-688	360.0	57.5	16.0	2.0	0.30	277	145.8	213	29.0	6512	140.8	377	25.0	5721	1

Table 997-2-3 ALLOWABLE TRIM DURING DOCKING (Cont.)

	STERN BLOCKS BUTTED		STERN BLOCKS SPACED 6 FEET CENTER TO CENTER							
							ALLOWABLE TRIM			
SHIP	C	SHIP (% L)	C1	C2	# OF BLOCKS BEARING (FULL LOAD)	APPLI-CABLE EQUA-TION #	FULL (ft)	LOAD (% L)	LIGHT (ft)	SHIP (% L)
AD-15	12.44	0.87	41.48	2.79	1.43	E11	3.49	0.67	4.03	0.78
AD-37	24.82	1.12	55.47	2.51	2.66	E11	2.71	0.44	3.63	0.59
AE-21	21.99	2.03	55.47	3.20	1.00	E11	5.09	1.05	6.79	1.40
AE-23	21.99	2.02	55.47	3.20	1.01	E11	5.05	1.04	6.75	1.39
AE-26	23.16	1.45	55.47	2.88	2.00	E11	3.01	0.56	4.76	0.88
AFS-1	22.95	1.75	55.47	2.93	1.26	E11	4.81	0.91	6.11	1.15
AOE-1	15.14	0.53	41.48	1.88	4.95	E11	1.41	0.18	2.68	0.35
AOR-1	13.79	0.69	41.48	2.27	2.82	E11	2.16	0.34	3.46	0.54
AO-177	12.80	0.90	41.48	2.64	2.00	E11	2.68	0.49	4.45	0.81
AO-98	13.54	0.75	41.48	2.35	2.00	E11	2.78	0.45	3.79	0.62
AR-5	12.44	0.88	41.48	2.79	1.47	E11	3.41	0.66	4.05	0.78
AS-11	22.73	1.68	55.47	2.99	1.20	E11	4.86	0.93	5.66	1.09
AS-19	23.67	1.46	55.47	2.76	1.68	E11	4.22	0.75	5.01	0.89
AS-31	23.80	1.43	55.47	2.73	1.94	E11	3.84	0.67	4.92	0.86
AS-33	24.82	1.12	55.47	2.51	2.64	E11	2.73	0.44	3.65	0.59
AS-36	24.82	1.13	55.47	2.51	2.69	E11	2.70	0.43	3.66	0.59
AS-39	24.82	1.13	55.47	2.51	2.69	E11	2.70	0.43	3.66	0.59
BB-61	29.23	0.74	332.83	47.90	2.00	E29	4.66	0.54	4.81	0.56
CGN-09	26.17	0.95	110.94	12.20	2.00	E20	4.51	0.65	3.93	0.57
CGN-25	12.67	0.69	82.96	14.56	1.81	E20	3.06	0.57	3.16	0.59
CGN-35	12.68	0.67	82.96	14.54	1.83	E20	3.05	0.56	3.10	0.57
CGN-36	13.03	0.61	82.96	13.77	2.00	E20	2.86	0.50	2.98	0.52
CGN-38	12.91	0.62	82.96	14.02	2.00	E20	2.87	0.51	2.97	0.53
CG-16	12.32	0.85	82.96	15.40	1.57	E20	3.20	0.63	3.53	0.69
CG-26	12.49	0.81	82.96	14.99	1.69	E20	3.13	0.60	3.51	0.67
CG-47	12.55	0.59	82.96	14.84	1.68	E20	3.17	0.60	2.67	0.51
CVN-65	32.15	0.49	332.83	39.60	3.00	E29	3.92	0.38	4.21	0.40
CVN-68	32.15	0.52	332.83	39.61	3.00	E29	3.78	0.36	4.41	0.42
CV-41	29.91	0.66	221.89	18.70	2.46	E23	4.14	0.46	5.00	0.56
CV-59	31.37	0.54	332.83	41.61	2.95	E29	4.05	0.41	4.36	0.44

Table 997-2-3 ALLOWABLE TRIM DURING DOCKING (Cont.) - Continued

	STERN BLOCKS BUTTED		STERN BLOCKS SPACED 6 FEET CENTER TO CENTER							
							ALLOWABLE TRIM			
SHIP	C	SHIP (% L)	C1	C2	# OF BLOCKS BEARING (FULL LOAD)	APPLI-CABLE EQUA-TION #	FULL (ft)	LOAD (% L)	LIGHT (ft)	SHIP (% L)
CV-63	31.37	0.58	332.83	41.61	2.89	E29	4.11	0.42	4.68	0.47
CV-67	31.37	0.55	332.83	41.61	3.00	E29	3.94	0.40	4.44	0.45
DDG-2	9.56	0.92	34.55	3.28	1.02	E11	3.04	0.72	3.70	0.88
DDG-40	12.08	0.98	41.48	2.96	1.35	E11	3.41	0.70	4.46	0.91
DDG-993	12.54	0.71	41.48	2.75	2.06	E11	2.17	0.41	2.95	0.56
DD-963	12.55	0.70	41.48	2.74	2.00	E11	2.24	0.42	2.95	0.56
FFG-1	9.21	1.17	34.55	3.53	1.00	E11	3.40	0.87	4.56	1.17
FFG-7	9.42	0.95	34.55	3.38	1.00	E11	3.41	0.84	3.72	0.91
FF-1037	7.23	1.00	27.61	3.66	1.00	E11	2.90	0.83	3.49	1.00
FF-1040	9.21	1.10	34.55	3.53	1.00	E11	3.71	0.95	4.23	1.08
FF-1053	9.50	1.00	34.55	3.32	1.04	E11	2.98	0.72	4.03	0.97
FF-1098	9.21	1.17	34.55	3.53	1.00	E11	3.40	0.87	4.56	1.17
LCC-19	11.23	0.41	34.55	2.38	5.00	E11	0.86	0.15	1.41	0.24
LHA-1	13.01	0.28	34.55	1.77	8.99	E11	0.67	0.09	0.91	0.12
LKA-112	10.72	0.82	34.55	2.61	1.18	E11	3.52	0.67	3.93	0.74
LPD-1	22.29	1.79	55.47	3.11	1.70	E11	3.71	0.74	5.97	1.19
LPD-4	12.77	0.91	41.40	2.65	2.00	E11	2.59	0.47	4.49	0.82
LPH-2	12.87	0.93	124.44	34.56	2.00	E27	2.86	0.51	3.05	0.55
LSD-37	12.68	0.88	41.48	2.69	2.00	E11	2.52	0.47	4.21	0.78
LSD-41	11.23	0.57	34.55	2.37	2.88	E11	1.69	0.29	2.50	0.43
LST-1179	10.43	0.83	34.55	2.75	1.32	E11	3.10	0.62	3.80	0.76
SSBN-608	11.06	1.19	41.48	3.53	1.00	E11	5.81	1.41	4.82	1.17
SSBN-616	11.25	1.04	41.48	3.41	1.00	E11	5.91	1.39	4.22	0.99
SSBN-627	11.25	1.04	41.48	3.41	1.00	E11	5.91	1.39	4.22	0.99
SSBN-640	11.25	1.04	41.48	3.41	1.00	E11	5.90	1.39	4.22	0.99
SSBN-726	23.58	1.37	55.47	2.78	1.00	E11	7.62	1.36	4.55	0.81
SSN-578	8.93	1.89	41.48	5.42	0.62	E11	6.22	2.32	4.86	1.82
SSN-585	8.56	2.19	41.48	5.90	0.60	E11	5.86	2.38	4.92	2.00
SSN-595	9.10	2.42	41.48	5.22	0.61	E11	6.58	2.37	5.89	2.12

Table 997-2-3 ALLOWABLE TRIM DURING DOCKING (Cont.) - Continued

	STERN BLOCKS BUTTED		STERN BLOCKS SPACED 6 FEET CENTER TO CENTER							
							ALLOWABLE TRIM			
SHIP	C	SHIP (% L)	C1	C2	# OF BLOCKS BEARING (FULL LOAD)	APPLI-CABLE EQUA-TION #	FULL (ft)	LOAD (% L)	LIGHT (ft)	SHIP (% L)
SSN-637	9.33	2.15	41.48	4.96	0.57	E11	7.35	2.51	5.78	1.98
SSN-688	10.35	1.76	41.48	4.03	0.68	E11	7.55	2.10	6.18	1.72

The constant C may be calculated as follows:

1. For single skeg and standard width blocks
   $C = \sqrt{[(SC_{KN} L) / 280]}$ (2 - 14)
   where

   C_{KN} = Compression of knuckle block (in) (see paragraph 997-2.5.2)

   L = Length between perpendiculars (LBP) (ft)

   S = Allowable unit stress (lb/in^2) at aft end of knuckle block disregarding stress concentrations under narrow keels or skegs. Stress concentrations are considered by varying S for different types of ships (see paragraph 997-2.5.2)

2. For twin skegs (CV-41), skegs over two feet wide or a wide keel with double width blocks (CV-59 class)
   $C = \sqrt{(SC_{KN} L / 140)}$ (2 - 15)

b. Spaced Blocks. For spaced blocks, 6 feet center to center, the allowable trim is given by:
   $t_a = C_1 [X_{KN} / (MT1'' + C_2 X_{KN})]$ (2 - 16)
   where

   t_a = allowable trim between perpendiculars (ft) (for most ships, this is essentially the same as the trim between draft marks)

   C_1 ,C_2 = see text below

   X_{KN} = distance from knuckle block to longitudinal center of flotation (ft)

   MT1″ = moment to trim one inch (ft-tons/in) The constants C_1 and C_2 are dependent upon the same factors as the constant C for butted blocks. They are also dependent upon the block spacing and number of blocks in contact with the keel at the time of maximum unit stress (when half the trim is removed) during pumping down or raising of the docking facility. Expressions for C_1 and C_2 when the blocks are spaced 6 feet center to center, are given in Table 997-2-4. For blocks at other spacings, C_1 and C_2 may be derived with the equations given in Appendix E. The values of C_{kn} and S in equations 2-14 and 2-15 are evaluated with careful consideration for stress-strain characteristics of docking blocks; safe allowable timber stress; and the effect of narrow skeg or keel (paragraph 997-2.5.2.3).

c. Approximation for Allowable Trim. An approximation of maximum allowable trim in feet may be computed by the following formula (except that the maximum allowable trim shall not exceed 1 foot per 100 feet of L):
   $t_a = ([.03(L)^2] / MT1'')$ (2 - 17)
   where t_a , L, and MT1″ are as noted previously.

997-2.5.5.3 Docking a Ship with Trim. When it is necessary or desirable to dock a ship with appreciable trim, both the total load on the knuckle block and the maximum unit stress at the after end of the knuckle block must remain within permissible limits. These permissible values will in turn depend upon the mechanical properties of the dock block timbers, in a direction perpendicular to the grain. If required, when docking in a floating dock, the dock may be trimmed to match the ship's trim.

997-2.5.6 LIST CONSIDERATIONS. A ship entering dry dock should be without list. If practicable, all list should be eliminated before attempting to dock the ship. If examination of the ship by the docking activity's representatives is not possible before docking, the Commanding Officer of the ship shall inform the activity of the amount of list, and its probable cause. This information shall be furnished sufficiently in advance of the time of docking to permit safe docking arrangements to be made without delaying the docking. The following paragraphs discuss list and negative stability.

Table 997-2-4. EXPRESSIONS FOR CONSTANTS WITH BLOCKS SPACED SIX FEET APART

No. of Blocks	Equation No. (See Appendix E)	C_1	C_2
1	E11	6.67	$\frac{S}{C_{KN}} \quad \frac{1.58S}{L}$
2	E20	6.67	$\frac{2S}{C_{KN}} \quad \frac{8.55S}{L}$
2 (with twin skegs or double width blocks)	E23	6.67	$\frac{4S}{C_{KN}} \quad \frac{17.10S}{L}$
3	E27	6.67	$\frac{3S}{C_{KN}} \quad \frac{20.93S}{L}$
3 (with twin skegs or double width blocks)	E29	6.67	$\frac{6S}{C_{KN}} \quad \frac{41.86S}{L}$
NOTES:			
1. Equation (E11) is applicable to the following hulls: destroyer and escort type ships, auxiliary ships.			
2. Equation (E20) is applicable to the following hulls: cruisers, Maritime Commision P2 (AP 111 class)			
3. Equation (E23) is applicable to the Midway class (CV 41)			
4. Equation (E27) is applicable to large ships such as CV, LPH			
5. Equation (E29) is applicable to the Forrestal class (CV 59) and later CV's).			

997-2.5.6.1 Reducing a Ship's List. In the majority of cases, list is caused by either an inherent asymmetrical condition of the ship or asymmetrical loading. Correction of list is most readily accomplished by either shifting fuel or water between port and starboard tanks or by placing small heeling weights on the main deck. For large ships, or large angles of heel on smaller ships, shifting of liquids will be the most practical method. The addition of topside weight raises the center of gravity and decreases the metacentric height (GM), resulting in decreased stability (for example, this is especially true for the FFG-1 and FF-1040 class ships). Similarly, the shifting of liquids can lower the stability if free surface in large tanks, such as inner bottom tanks, is increased inordinately. When transferring liquids to reduce list, it is advisable to shift liquid from tanks already slack to tanks already partially full.

997-2.5.6.2 Negative Stability. While list is usually caused by asymmetrical loading, the Docking Officer or the contractor's Dockmaster should first determine the cause of the list and ascertain that it is not due to negative stability (negative value of metacentric height, GM). While ships having negative GM will seldom be encountered, it is, however, important that the condition be recognized when it occurs. A check of the stability data aboard the ship will quickly indicate if this is at all possible. If negative stability is indicated, the ship's bottom tanks shall be ballasted to an extent that adequate stability for docking exists. The condition of a ship listing from one side to another without any apparent reason is known as lolling. It is an indication of negative GM or righting arm in the upright position. A ship in this condition is unsafe to drydock.

997-2.5.6.3 Docking a Ship with List. It is practical to dock a ship with a very small list by slowly landing the ship on the downside side blocks and rolling out the list. The ship should have as little trim as possible when using this method. If it is intended to land a ship with a list, it will be necessary to apply a centerline correction when initially positioning the ship over the blocks while it is afloat. If this is not done, the ship will be off center after it has landed and righted. The draft allowance in feet at the waterline is equivalent to:

D tan (2 - 18)

where

D = draft of ship at its keel (centerline) (ft)

= angle of heel (degrees).

If the difference between the midship drafts port and starboard in feet is denoted by (δD) and the beam of the ship by B, then

tan (/B) = (δD) (2 - 19)

and the amount of offset correction in feet (Z) at the waterline will be:

Z = [D(δD)] / B (2 - 20)

The correction is to be applied athwartship in the direction of the low side of the ship (see Figure 997-2-3).

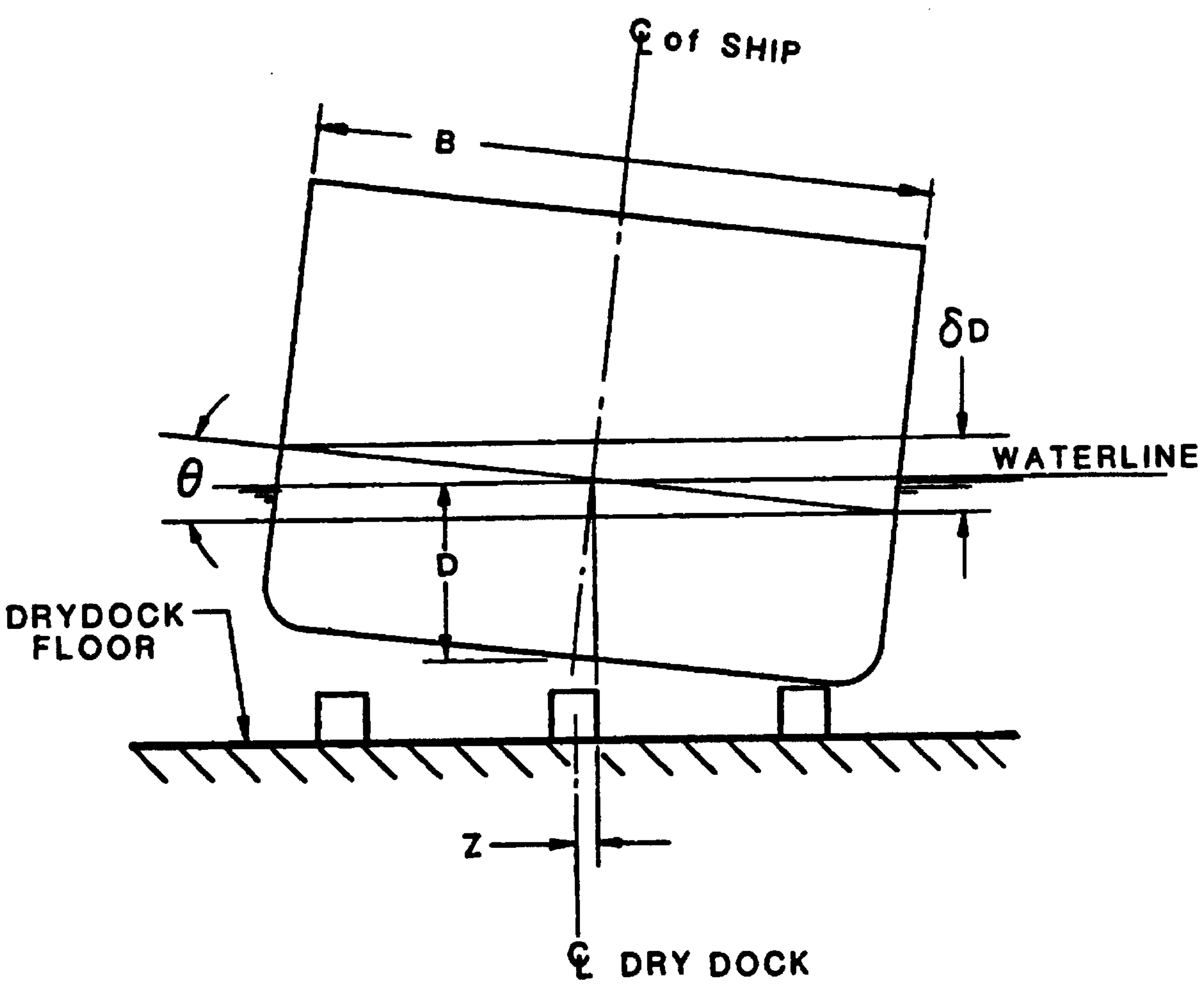


Figure 997-2-3. Docking a Ship with List

SECTION 3.

SAFETY PRECAUTIONS FOR SHIPS IN DOCKING FACILITIES

997-3.1 GENERAL

997-3.1.1 To ensure the safety of ships in docking facilities, comprehensive and effective operating procedures shall be prepared by the docking facility operator to address security, fire watches, prevention of flooding, and disaster planning. These procedures become a part of the docking facility's approved Facility Certification Report or Facility Recertification Report. MIL-STD-1625, Safety Certification Program for Drydocking Facilities and Shipbuilding Ways for U.S. Navy Ships , provides guidance for developing these procedures. That guidance is not repeated here; however, there are several key areas of operational concern which should be highlighted, and they are addressed in the following paragraphs.

997-3.2 DAMAGE CONTROL AND FIRE PROTECTION

997-3.2.1 A comprehensive and effective damage control and fire protection plan, including implementing systems, shall be operational while the ship is in the docking facility. The plan shall remain in force until the ship departs from the facility. The fire protection program shall be in accordance with Naval Sea Systems Command Instruction (NAVSEAINST) 5100.16.

997-3.3 SHIFTING OF WEIGHTS

997-3.3.1 No weight, including liquids such as fuel or water, shall be shifted, added, or removed from the ship while the ship is in the docking facility unless specifically authorized by the Docking Officer or the contractor's Dockmaster. When permission is given to shift weight, responsibility for keeping an accurate record of the amount and location of the weight change accomplished by the ship's personnel rests with the ship's Commanding Officer. Responsibility for keeping an accurate record of weight changes accomplished by the shipyard, in conjunction with the drydock work and not at the specific request of the ship, rests with the shipyard. In all cases, weight should be arranged at the time of flooding or lowering for undocking to ensure having the ship lift from the blocks without taking an undue list.

997-3.4 CLOSING OPENINGS AT NIGHT

997-3.4.1 For ships in commission, Article 0753, United States Navy Regulations, 1979, sets forth the requirements on closing openings in the ship's bottom outside working hours (see also NSTM Chapter 505, Piping Systems). For ships without crews, whenever failure of docking or lifting facilities could result in flooding through unattended hull openings which are open for repair or examination, the shipyard shall, at the end of each work shift not immediately followed by a shift engaged in work on all of these openings, secure all intact sea chest and overboard discharge valves or fit temporary closures to these and to all other hull openings upon which work is being undertaken. In addition, when the area of shell plating removal makes temporary closure impractical, the shipyard shall secure each vulnerable compartment in order to minimize potential damage. To the extent permitted by scope and urgency of work, underwater hull operations shall be scheduled to maintain positive ship stability and maximum hull watertight integrity to help ensure the ship's safety in case the docking facility inadvertently becomes flooded.

997-3.5 FLAMMABLE LIQUIDS

997-3.5.1 No fuel oil, gasoline, or other flammable liquid shall be pumped or drained into the docking facility. When it is necessary for a ship in a docking facility to discharge any liquid from a gasoline tank, fuel oil tank, or other flammable liquid tank, such liquid shall be discharged only under shipyard supervision into a special container, even if it is estimated that the tank contains no gasoline, fuel oil, or other flammable liquid. The shipyard shall take necessary precautions if the liquid is found to contain flammables.

997-3.6 SEWER DISCHARGING WHILE DOCKED

997-3.6.1 In docking facilities fitted with direct sewer connections, the officers' water closets and wash rooms, the crew's heads and wash rooms, the galley, and the laundry can be connected to the sewer and used at all times, except when special occasions make it necessary to shut down. The Docking Officer or the contractor's Dockmaster will notify the Officer of the Deck when necessary to shut down and, when so requested, the Commanding Officer will ensure prompt compliance with the request.

997-3.6.2 Where docking facilities are not fitted with direct sewer connections or holding tanks, all soil drains shall be secured. Officers' and crew's wash rooms and showers, galleys, and laundries may be used only with the water draining directly into the docking facility, if permission to do this is obtained from the Docking Officer or the contractor's Dockmaster. However, neither fresh water nor seawater shall be drained into the docking facility unless approval has been given by the Docking Officer or the contractor's Dockmaster.

997-3.7 DRAINING VALVES AND PIPES

997-3.7.1 When ambient temperatures have reached or are expected to reach freezing, valves, pipes, or similar fittings attached to the shell of a docked ship shall be examined, and any remaining water shall be drained to prevent freezing and possible cracking of the fittings.

997-3.8 DOCK RAILS AND STANCHIONS

997-3.8.1 Hand rails, safety lines, and stanchions around docking facilities shall be maintained in good condition at all times and shall be kept in place, except during the actual operations of docking and undocking ships.

997-3.9 INCINERATORS

997-3.9.1 All incinerators shall be secured and may be used only if permission is obtained from the Docking Officer or the contractor's Dockmaster.

997-3.10 GRAVING DOCK CAISSON

997-3.10.1 When docking in a graving dock, the caisson shall neither be deballasted nor removed until the water level is approximately the same on both sides; however, each activity operating a graving dock shall establish maximum limits on the water level difference at deballasting, based on operational and safety requirements of the particular caisson and dry dock.

997-3.11 MAJOR CAUSES OF DOCKING FACILITY CASUALTIES

997-3.11.1 The following list outlines the major causes of past docking facility casualties:

a. Unsuitable number, distribution, or type of supporting blocks

b. Inaccurate ship positioning within the docking facility

c. Excessive overhang of ship's ends

d. Relative motion of the ship and the docking facility, mainly caused by lack of protection from adverse environmental conditions

e. Operator error

f. Unauthorized or inadvertent shifting of liquids aboard the ship

SECTION 4.
WORK ON SHIPS IN DOCKING FACILITIES

997-4.1

Routine work performed on ships in dry dock normally consists of that work which can be conveniently accomplished only when the ship is out of the water and its hull, propeller, and appendages are easily accessible. Typical of this type of work are the following:

a. Inspect and repair rudder, propeller, and shafting

b. Inspect and repair sonar domes

c. Inspect and repair sea valves and sea chests

d. Paint hull

e. Inspect and repair cathodic protection system

997-4.2

The particular work performed varies greatly between ship types (e.g., submarines, surface combatants, and auxiliaries) and classes and is tailored to the ship's selected restricted availability (SRA) or overhaul schedule, the repair and maintenance needs of the ship, and the available resources.

997-4.3

Overall guidance concerning the work to be performed is documented in Class Maintenance Plans for surface ships, and Nuclear Submarine Baseline Overhaul and Selected Restricted Availability Work Packages for submarines (nuclear and nonnuclear). Through Type Commander review and approval, these plans and work packages are revised to meet the needs of individual ships for each docking.

SECTION 5.

UNDOCKING PROCEDURE

997-5.1 RESPONSIBILITY FOR UNDOCKING

997-5.1.1 The responsibilities of the Commanding Officer and the Docking Officer in undocking ships are set forth in Article 0752, United States Navy Regulations, 1979 . All undockings in naval facilities shall be supervised by an officer who has been given specific training and has been certified as a qualified Docking Officer in accordance with applicable Navy instructions. When undocking in commercial facilities, the Representative of the Supervisor of Ship Building (SUPSHIP) shall ensure that the contractor's Dockmaster is professionally qualified through training and experience and that his/her qualifications are a matter of record.

997-5.2 ADVANCE PREPARATIONS FOR UNDOCKING

997-5.2.1 UNDOCKING ARRANGEMENTS. Undocking arrangements will be agreed upon during a pre-undocking conference. This conference shall be attended by, as a minimum, the Commanding Officer and the Engineering Officer of the ship to be undocked and (if at a naval facility) the Docking Officer, or (if at a commercial docking facility) the SUPSHIP Representative and the contractor's Dockmaster. This conference shall be arranged sufficiently prior to the undocking date to permit the incorporation of all details required in the undocking.

997-5.2.1.1 The following considerations shall be included:

a. Time and date of undocking

b. Time and date that flooding of the floating or graving dock, or lowering of the vertical lift platform will start

c. Tugs and Pilots required for undocking ships shall, if possible, be furnished by the Shipyard Commander from those regularly assigned to the shipyard. If tugs are not regularly assigned to the shipyard, tug service should be requested from the Naval Base Commander. If additional tugs are required, they shall be obtained by requisition under the appropriation supporting the docking establishment. All tug Captains and Pilots shall be thoroughly briefed by the Docking Officer or contractor's Dockmaster on regulations, instructions, and authority as applicable to the undocking. It is imperative that all pilots handling U.S. naval ships in and out of dry docks and vertical lift facilities follow the Navy regulation that the responsibility for control of the ship is vested in the Docking Officer or the contractor's Dockmaster until the moment the extremity of the ship last to leave the dock passes the dock sill. Failure of Pilots and tugs to respond to the Docking Officer or contractor's Dockmaster during undocking shall be cause for debarment from future naval ship undocking functions.

d. In the case of a ship in commission, the shipyard shall request that the ship to be undocked furnish working parties to handle lines, sound tanks, and attend hull openings. If the ship's crew is too small to furnish working parties, the Commanding Officer shall so inform the shipyard. Arrangements will then be made to obtain working parties from some other ship at the shipyard or to detail yard labor, as directed by the shipyard Commander. If the ship is out of commission or otherwise without a crew, working parties shall be detailed by the shipyard for the following tasks:
   1. To handle lines during the undocking
   2. To sound all ship tanks within 12 hours prior to undocking (reports of the soundings shall be forwarded to the Docking Officer or SUPSHIP Representative before the undocking operation commences)
   3. To attend hull openings during undocking

e. Berth to which ship will be moved after leaving the dock

f. Date by which Shift of Weight Report shall be received

g. Methods of communication between personnel at various docking stations on the floating dock, graving dock or vertical lift platform, and on ship, tugs, and so forth

997-5.2.1.2 Using the resulting agreements on docking arrangements and the operating procedures specified in the docking facility as approved Facility Certification Report or Facility Recertification Report (as specified in MIL-STD-1625, Safety Certification Program for Drydocking Facilities and Shipbuilding Ways for U.S. Navy Ships), the following shall be prepared by the Docking Officer or the contractor's Dockmaster for use dur ing docking operations for each ship:

a. Sequence and description of important steps

b. Pumping and flooding plan (where applicable)

c. Docking logs and checklists showing required data entries and verification signatures for the docking evolution

997-5.2.2 DOCK BLOCKING PREPARATION. The Docking Officer or the contractor's dockmaster shall determine that at the scheduled undocking time there will be ample water to ensure that the ship will clear all of the blocks, taking into account any underwater projections that may have been installed on the ship while in dock.

997-5.2.2.1 A minimum clearance of 12 inches between the ship (or nearest appendage) and the docking blocks shall be maintained during the undocking evolution. Also, in floating dry docks a minimum clearance of 12 inches shall be maintained between the dock and the harbor bottom. Clearances less than 12 inches pose a significant risk which is acceptable only in emergency situations.

997-5.2.2.2 Note that tidal changes do not affect the amount of water over the blocks in a floating dry dock. However, tidal changes will affect the amount of water under a floating dry dock.

997-5.2.2.3 The Docking Officer or contractor's Dockmaster shall inspect the docking facility, the ship, and the blocking, ensuring that all blocking is securely dogged to prevent it from floating after the ship is waterborne and to ensure that both the ship and the docking facility are ready for flooding or lowering to begin.

997-5.2.3 WEIGHT CHANGES. The Commanding Officer of a ship being undocked shall make a report to the Naval Architecture Weight Section in a naval shipyard or the person responsible for weights in a commercial shipyard (both referred to here as the Weight Section, for brevity) of all significant weights shifted on the ship by the ship's force. The Manager of the ship overhaul shall make a report to the Weight Section of all significant weights shifted by shipyard and contractor personnel. These reports shall be received sufficiently in advance of the scheduled undocking to permit determination by the shipyard of any changes in ship stability because of weight changes. Prior to undocking, the Weight Section shall update calculations showing the ship in Condition A, i.e., light ship weight - including margin and parts and operating fluids but no fuel and no consumables - as it leaves the docking facility. Calculations shall be performed to determine the variable load required to bring the ship out of dock in proper trim and list. Draft readings shall be taken when the ship is waterborne and clear of the dock to prove calculation accuracy. The Weight Section shall prepare an overall report and deliver it to the Docking Officer or (for a commercial shipyard) contractor's Dockmaster and the SUPSHIPS Representative.

997-5.2.4 CONNECTIONS. Unnecessary sewer and other service connections between the ship and the docking facility shall be removed. Handling lines shall be run from the ship to the floating or graving dock's side walls or to the vertical lift's side platforms; and lines for hauling the ship out of the docking facility shall be installed.

997-5.2.5 SIGHTING MARKS. Bow, stern, and centerline sighting marks shall be provided so the ship may be re-landed, if necessary.

997-5.2.6 REPORT OF LEAKAGE. Before any flooding or lowering of the docking facility has begun, the ship's Commanding Officer shall submit a report to the Docking Officer or the contractor's Dockmaster that all sea valves are closed and that personnel are stationed to observe tightness (see Article 0753, United States Navy Regulations, 1979). The Docking Officer or the contractor's Dockmaster shall receive a report that all sea valves are closed and the yard force is stationed to observe tightness.

997-5.2.7 DRAFTS AND LIST WHEN SHIP LIFTS. Based on the change of weight reports and docking drafts of the ship, the Docking Officer or the contractor's Dockmaster shall calculate or have calculated to his/her satisfaction, the predicted drafts and list of the ship when it is lifted from the blocks and shall ensure proper ballasting, if necessary.

997-5.2.8 EXCESSIVE HEELING. Compensation shall be provided for excessive heeling moment, if such is indicated by the reported weight changes. If significant topside weight changes occurred during the drydocking period, a calculation shall be made to ensure that positive stability exists.

997-5.2.8.1 At the discretion of the Docking Officer or the contractor's Dockmaster, the quadrant method for detecting and correcting an excessive heeling moment during undocking may be used (in addition to calculations) where considerable change in heeling moment is likely to have occurred. It should be noted that this method requires extreme care and shall be accomplished only by experienced personnel.

997-5.2.8.2 The quadrant method makes use of the phenomenon that, as a dry dock is flooded or a vertical lift is lowered, the buoyant effect of the water on the ship's hull raises the light side of the ship first, thus pivoting the ship slightly about its heavy side. This pivoting has been found to begin at about one-fourth of the draft required to float the ship (e.g., at the 5 foot draft for a ship whose draft is 20 feet) and then to increase as the undocking progresses. A quadrant with a scale of seven graduations per minute of arc is typically of sufficient resolution for use in this type of observation.

997-5.2.8.3 The recommended quadrant method is to use one quadrant, located at the end of the ship which will float first. The quadrant should be attached to a part of the ship (such as a transverse frame) which is not subjected to local deflections. Readings should be taken until close to the predicted flotation draft of the ship. At that point, ballast should be added or transferred athwartship to bring the readings half way back to their original values. Then the undocking should resume.

997-5.2.9 FACILITY CLEAN-UP. Prior to undocking, all debris, blast grit, staging equipment, floatable objects, and so forth, which may endanger or interfere with the undocking operation shall be removed from the docking facility.

997-5.3 THE UNDOCKING OPERATION

997-5.3.1 FORMALITY OF DOCKING FACILITY OPERATING PROCEDURES. The requirements of paragraph 997-2.3.1 apply.

997-5.3.2 PRESENCE OF DOCKING OFFICER, SUPSHIPS REPRESENTATIVE, AND CONTRACTOR'S DOCKMASTER. The requirements of paragraph 997-2.3.2 apply.

997-5.3.3 STATIONING OF PERSONNEL. The requirements of paragraph 997-2.3.3 apply.

997-5.3.4 WEATHER AND TIDAL CURRENTS. The requirements of paragraph 997-2.3.4 apply.

997-5.3.5 COMMENCING THE UNDOCKING OPERATION. The Docking Officer or the contractor's Dockmaster shall flood the floating or graving dock, or lower the vertical lift platform to a depth that will cover as many sea valves and other openings as possible without lifting the ship off the blocks. If a leak is reported prior to reaching this point, the severity of the leak shall be determined. If the leak is not serious, flooding or lowering shall continue to desired depth to cover other openings and to determine the existence of any other leaks. If the leak is serious, flooding or lowering shall be stopped or reversed, as appropriate, until the leak is stopped or reduced to a non-serious magnitude. At that time, the flooding or lowering may continue.

997-5.3.6 DETECTING AND CORRECTING ASYMMETRICAL TRANSVERSE LOADING. Asymmetrical transverse loading may be detected using either the quadrant method or the block level (inclinometer) method, as described above. It will be assumed here that the quadrant method is being used.

997-5.3.6.1 When the incipient heel has become sufficient to yield a sizeable bubble reading, flooding of the dock shall be stopped, and weights (usually liquids) transferred from the heavy side to the light side of the ship, voids or tanks or both. Sufficient weight shall be transferred or added so that the quadrant bubble will recover one half to three fourths of its original travel from the zero position. The exact bubble travel will depend upon the draft at which the weight transfer is undertaken and the stress-strain characteristics of the block capping.

997-5.3.6.2 After the first moment correction has been made, flooding or lowering shall be resumed at a slow rate. If excessive migration of the quadrant bubble again develops prior to actual lift from the blocks, flooding or lowering shall be stopped and a supplemental weight transfer made. In some cases, where clearances between sponsons and wing walls or side platforms of the docking facility are critical, it may be necessary to make a third weight correction, in order to ensure that the ship will be essentially plumb when it becomes fully waterborne.

997-5.3.6.3 If there is any possibility of negative metacentric height, the final stages of flooding or lowering shall be carried out with extreme caution so that the operation may be halted instantly if the ship begins to heel appreciably. With negative metacentric height there will be no warning from the quadrants until the ship starts to lift from the blocks. In other words, if the quadrant readings become increasingly larger as the flooding or lowering reaches higher and higher ship drafts, it is apparent that off-center weights are causing the trouble. On the other hand, if the quadrants show no significant readings until the ship is just lifting and then suddenly show very large values, it is due to negative metacentric height and the docking facility shall be pumped down or raised slightly until suitable remedial measures are effected.

997-5.3.6.4 This outline is to be used as a guide in preparing the detailed procedure for the quadrant method of undocking at each activity. The use of the quadrant method is not intended to take the place of usual safety precautions while undocking.

997-5.3.7 CONCLUDING THE UNDOCKING OPERATION. The Docking Officer or the contractor's Dockmaster shall receive a final report from the ship's Commanding Officer and the activity stating that the ship is ready for complete flooding or lowering of the docking facility. Flooding or lowering shall then be resumed until the water level is the same on both sides of the caisson of a graving dock or between the wing walls or side platforms of vertical lift facilities. The Docking Officer or the contractor's Dockmaster shall verify that tugs and a Pilot are in readiness; that riggers, pump, winch, crane or hoist operators, and shipwrights are properly stationed; and that all lines are properly run. The gangway is then removed. Finally, the caisson is removed if undocking from a graving dock.

997-5.3.8 TRANSITION FROM HANDLING BY LINES TO SHIP OR TUG PROPULSION. The Docking Officer or the contractor's Dockmaster shall direct the handling of lines to ensure safe exit of ship from the docking facility.

997-5.3.8.1 The ship's speed shall be kept minimal, because a ship moving too fast over the blocks may knock the blocks over.

997-5.3.8.2 Approximately half way out, depending on the size of the ship and the shape of the entrance to the docking facility, the ship is slowed or stopped to permit attachment of lines to tugs. Tugs shall not be permitted in the area of a graving or floating dock's sill or the offshore sill of a vertical lift platform where they might damage the drydock caisson seat or the end structure of other types of docking facilities. Through the Pilot, the Docking Officer or the contractor's Dockmaster shall direct the remainder of the safe movement of the ship from the docking facility.

997-5.3.9 EXCHANGE OF RESPONSIBILITY AND OPERATIONAL CONTROL. As the extremity of the ship last to leave the dock reaches the dock sill, and the ship is pointed fair for leaving the dry dock or vertical lift platform, the Commanding Officer of the ship relieves the Docking Officer or the contractor's Dockmaster of responsibility for the safety of the ship. At this point, the Pilot also relieves the Docking Officer, or the contractor's Dockmaster of operational control of the ship and tugs (see Article 0752).

997-5.4 ACTION AFTER UNDOCKING

997-5.4.1 ACCOUNTING FOR DOCKING BLOCKS. The Docking Officer or contractor's Dockmaster shall account for the presence of all docking blocks after the ship has left the docking facility. In extremely low temperatures, docking blocks may adhere to the bottom of the ship.

997-5.4.2 UNMANNED SHIPS AND SERVICE CRAFT SECURITY. Unmanned ships shall be visually inspected for watertight integrity at least every 4 hours for a minimum of 24 hours after the undocking inspection.

997-5.4.3 DOCKING REPORT. The docking report shall be prepared and forwarded in accordance with paragraph 997-1.4.1.

APPENDIX A.

NUMERICAL EXAMPLES OF LANDING DRAFT AND STABILITY DURING DOCKING

997-A.1 GENERAL

A.1.1 Calculations for draft at landing and for instability while drydocking are provided in this appendix. Pertinent data on the FF-1052 is as follows:
Draft forward (H_F) = 15.44 ft
Draft aft (H_A) = 15.64 ft
Mean Draft (H_m) = 15.54 ft
Displacement (Δ). (from hydrostatic curves) = 4255.56 tons
Length between perpendiculars (L) = 415 ft
KG (from inclining experiment) = 17.45 ft
Trim (t), by stern = 0.20 ft = 2.4 in
Moment to trim one inch (MT1″), (from hydrostatic curves) = 820 ft-tons
Longitudinal center of buoyancy (LCB), (from hydrostatic curves) = 0.20 ft aft of Midships
Longitudinal center of gravity (LCG) (from the damage control book, chapter II(a) or the ship's inclining experiment) = 0.65 ft aft of Midships
Longitudinal center of flotation (LCF), (from hydrostatic curves) = 27.3 ft aft of Midships
Length of keel block system (from docking drawing = 272 ft
Distance, aft end of knuckle block to Midships, (from docking drawing) = 132 ft forward
Distance, aft end of knuckle block to LCG (d), (calculated) = 131.35 ft forward
Distance, aft end of knuckle block to LCF (X_{KN}), (calculated) = 104.7 ft forward
Tons per inch immersion (TP1'0, (from hydrostatic curves) = 34 tons/in

Trimming lever = [(t)(12)(MT1″)] / Δ

= [(.20)(12)(820)] / 4255.56

= .462 feet, aft of LCB.

997-A.1.2 To find the draft at landing fore and aft, the residual buoyancy moment about the knuckle block versus the draft is plotted on the same graph as the weight moment about the knuckle block. Table 997-A-1 presents the calculations for residual buoyancy moment at various drafts. Since the ship's weight and the distance from the center of gravity to the knuckle block do not vary with draft, the weight moment will appear as a vertical line on the graph. The point at which these two lines intersect is the draft at which the ship lands fore and aft (see Figure 997-A-1).

997-A.2 CALCULATION OF STABILITY

997-A.2.1 To find the stability at landing, equation (2-12) is solved graphically. The residual stability moment about the metacenter [(Δ - R_{KN})KM_1] versus the draft is plotted on the same graph as the weight moment about the vertical center of gravity (ΔKG). Table 997-A-2 presents the calculations of the residual stability about the metacenter. Since the ship's weight and vertical center of gravity do not vary with draft, the weight moment will appear as a vertical line on the graph. The point at which these two lines intersect is the draft at instability (see Figure 997-A-2).

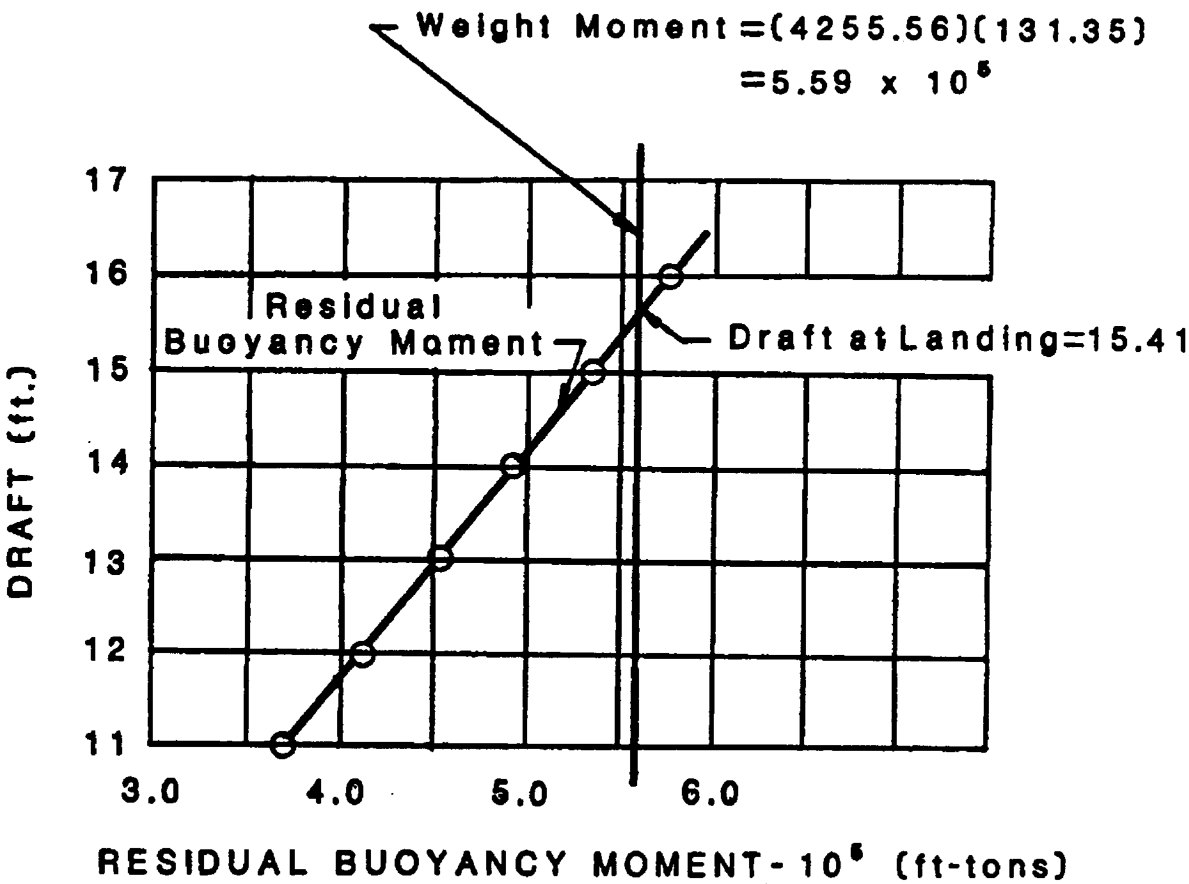
997-A.2.2 If the draft at instability is much lower than the draft at landing fore and aft, the ship will dock safely (for example, if the draft at instability is 13.1 feet and the draft at landing is 15.4 feet, then the ship will remain stable during docking).

997-A.3 EXACT METHOD

997-A.3.1 Stability when a ship lands can be computed using equation (2-11) along with data from the curves of form. The residual buoyancy is equal to the weight of the ship minus the knuckle block reaction. The metacentric height can be found directly from the curves of form (see Table 997-A-1 and Table 997-A-2). The stability when the ship lands is completed as follows:

Table 997-A-1. CALCULATIONS FOR DRAFT AT LANDING

(1)	(2)	(3)	(4)	(5)	(6)
Draft (ft)	**Dist., 0 to aft end of Knuckle block (ft)**	**Dist., LCB to 0 (from hydrostatic curves) (ft)**	**Dist., LCB to aft end of knuckle block (2) + (3) (ft)**	**Residual buoyancy (Δ - R_{kn}) (from hydrostatic curves) (tons)**	**Residual buoyancy moment (4) x (5) (ft-tons)**
11	132	14.6 (forward)	146.6	2567	3.76×10^5
12	132	11.0 (forward)	143.0	2896	4.14×10^5
13	132	7.3 (forward)	139.3	3257	4.54×10^5
14	132	4.2 (forward)	136.2	3636	4.95×10^5
15	132	1.2 (forward)	133.2	4036	5.38×10^5
16	132	1.2 (aft)	130.8	4444	5.81×10^5
NOTE: This table applies only to the FF-1052 example.					



NOTE: THIS FIGURE APPLIES ONLY TO THE FF 1052 EXAMPLE

Figure 997-A-1. Draft at Landing Curves

Table 997-A-2. CALCULATIONS FOR INSTABILITY WHILE DRYDOCKING

(1)	(2)	(3)	(4)
Draft (ft)	**Residual buoyancy, (Δ - R_{KN}) (from hydrostatic curves) (tons)**	**Height of metacenter above keel, KM_1 (from hydrostatic curves) (ft)**	**Moments (KM_1) (Δ - R_{KN}) (2) x (3) (ft-tons)**
11	2567	22.40	5.75×10^4
12	2896	22.45	6.50×10^4
13	3250	23.43	7.61×10^4
14	3636	22.37	8.13×10^4
15	4036	22.15	8.94×10^4

Table 997-A-2. CALCULATIONS FOR INSTABILITY WHILE DRYDOCKING - Continued

(1)	(2)	(3)	(4)
Draft (ft)	**Residual buoyancy, (Δ - R_{KN}) (from hydrostatic curves) (tons)**	**Height of metacenter above keel, KM_1 (from hydrostatic curves) (ft)**	**Moments (KM_1) (Δ - R_{KN}) (2) x (3) (ft-tons)**
16	4444	21.90	9.73×10^4
NOTE: This table applies only to the FF-1052 example.			

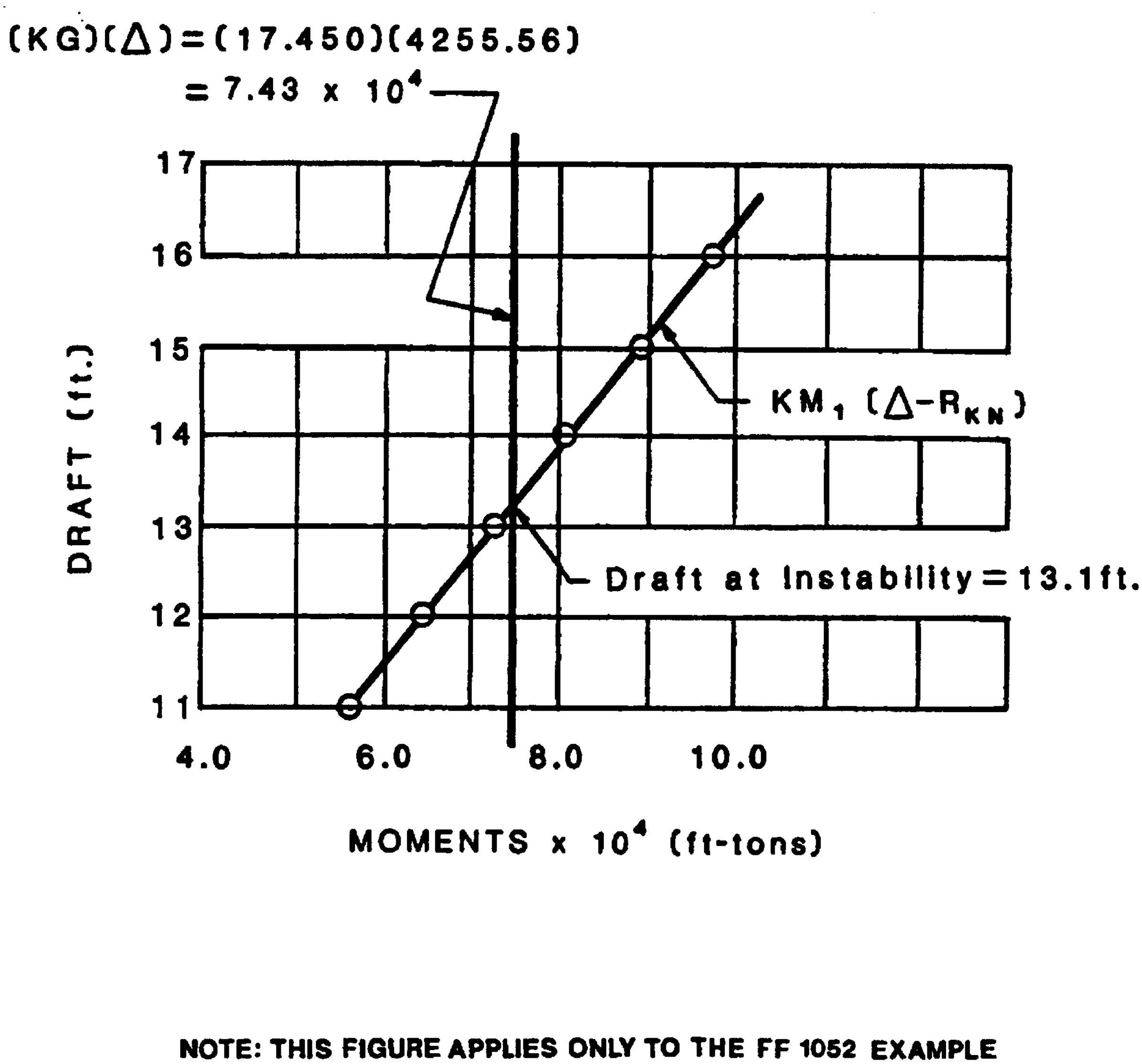


Figure 997-A-2. Limit of Stability Curves

$G_v M_1 = KM_1 - (\Delta(KG)) / (\Delta - R_{KN})$ (2 - 11)
where KM_1 = height of meta center above the keel = 22.10 ft

$(\Delta\text{-}R_{KN})$ = the residual buoyancy = 4202.33 LT
therefore
$G_v M_1 = 22.10 - ((4255.56)(17.45)) / 4202.33$
$\Delta = 22.10 - 17.67$
$G_v M_1 = 4.43$ ft

997-A.4 APPROXIMATION OF STABILITY AND DRAFT.

997-A.4.1 The approximate method for finding draft and stability at landing is as follows for this example:
$R_{KN} = (t)(MT1'') / kX_{KN}$ (2 - 9)
$R_{KN} = [(2.4)(820)] / [(.94)(104.7)]$
= 20.00 tons
$H_1 = H_m - (R_{KN} /[(12)(TP1'')])$ (2 - 10)
= 15.54 - [20.00 / 12(34)]
= 15.54 - .05
= 15.49 ft
$G_v M_1 = KM_1 - [(\Delta\ KG) / (\Delta\text{-}R_{KN})]$ (2 - 11)

$(\Delta - R_{KN})$ @ 15.49 W.L. = 4255.56 - 20.00 = 4235.56 tons
$G_v M_1$
= 22.10 - ([(4255.56)(17.45)] / 4235.56)
= 22.10 - 17.53 = 4.57 ft.

997-A.5 RULE OF THUMB TO FIND DRAFT AT LANDING.

997-A.5.1 A rule of thumb method (which is less accurate than either of the above two methods) to find draft at landing is as follows:

$H_1 = H_D\ 2/3(H_A - H_F) = H_D - 2/3t$

= 15.54 - 2/3(.2)

= 15.54 - .13

= 15.41 ft.

where
H_D = deep draft, which is the larger of the two variables, H_F and H_A (in this case, H_A is used)

APPENDIX B.

KNUCKLE REACTION GENERAL PRINCIPLES

997-B.1

When a ship with trim aft is being drydocked, and the water level in the drydock well is falling, the ship will first come in contact with the aftermost keel block, generally known as the knuckle block. As more water is pumped out, the decrease in the ship's buoyancy has to be compensated by an increase in knuckle reaction such that at any instant the knuckle reaction plus the buoyancy will equal the ship's original floating displacement.

997-B.1.1 In the floating, trimmed, condition the ship's longitudinal center of buoyancy (LCB) and the ship's longitudinal center of gravity (LCG) are colinear. As the dock begins to lift the ship through the knuckle block and the ship's buoyancy decreases, the ship's center of buoyancy moves forward; likewise, the trim decreases. At all times, two equilibrium conditions must be satisfied:

a. The knuckle block reaction plus the residual buoyancy must equal the ship's weight (original floating displacement).

b. The moment of the knuckle block reaction about the ship's longitudinal center of gravity, must equal the moment of the residual buoyancy about the LCG. These relationships are shown in Figure 997-B-1.

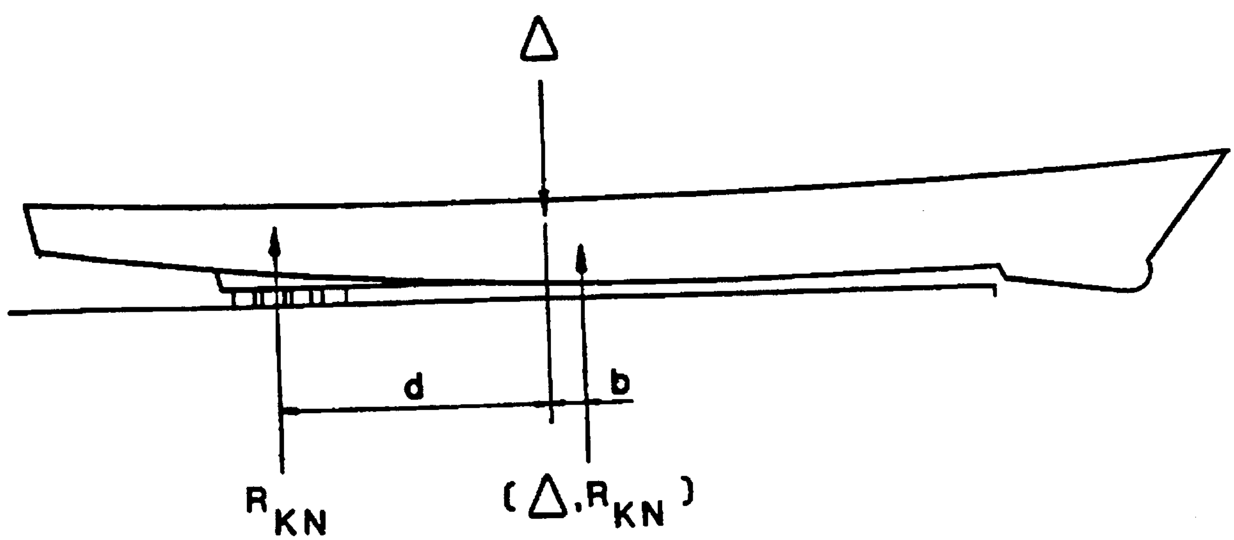


Figure 997-B-1. Knuckle Block Reaction in Drydocking

The equilibrium conditions are:

$\Delta = R_{KN} + (\Delta - R_{KN})$ (B1)

$dR_{KN} = b(\Delta - R_{KN})$ (B2)

where:

Δ = displacement (tons)

R_{KN} = knuckle reaction (tons)

$(\Delta - R_{KN})$ = residual buoyancy (tons)

d = distance from LCG to resultant knuckle reaction (ft)
b = distance from LCG to LCB of ship at any instant during pump down (ft).

997-B.1.2 At various stages in trimming-out process these equilibrium conditions may be established using Bonjean curves, and the knuckle reaction, as well as the drafts forward and aft, determined. Bonjean curves are curves showing the relation between transverse area of hull and draft at any particular station.

APPENDIX C.

COMPUTATION OF KNUCKLE REACTION USING LCF AND MT1″ VALUES

997-C.1

In most instances, a satisfactory value of knuckle reaction may be obtained by using data taken from the docking drawing or from the curves of form (in special cases, such as when a ship is damaged, a more stringent approach, using Bonjean Curves, may be necessary). If one considers that the knuckle reaction is equivalent to a weight removed at the keel, it is obvious that, if this weight were removed directly below the center of flotation, no tendency would result for the ship to change trim. On the other hand, if the reaction is moved aft from the point directly under the center of flotation to its actual position at the stern blocks, the effect is the same as that of removing a weight near the after end of the ship, and a trimming moment forward is inevitable. The decrease in trim which will accompany a given knuckle reaction will be inversely proportional to the moment to trim 1 inch (see equations C1 through C3).

997-C.1.1 In actual practice no attempt is made to utilize varying values of LCF and MT1″ as the trimming-out process evolves. Such a procedure would involve calculations from first principles and would be far too laborious and time-consuming for the ordinary problems of drydocking. Instead, the LCF and MT1″ values in the even keel condition are used throughout. These values are, of course, easily obtainable from either the docking drawing or from the curves of form.

997-C.1.2 Furthermore, no attempt is made to move the resultant of the knuckle reaction forward as the trim decreases and brings more blocks into contact with the keel. Although this detail is exceedingly important just before the ship lands all along the keel blocks, it is of no consequence until 80 or 85 percent of the trim has been removed, whereas maximum knuckle stress and maximum knuckle block load occur when about half of the trim has been eliminated (refer to appendix D).

997-C.1.3 Although the approximations regarding LCF and MT1″ yield a knuckle reaction somewhat too low, the error is of the order of only 10 percent, and inasmuch as an error of 10 percent in the knuckle reaction will produce an error of only 5 percent in the maximum knuckle stress (appendix D), the method is sufficiently accurate for most drydocking trim calculations. Equation (2-17) in paragraph 997-2.5.5.2.3.2.c is an approximation formula.

Equating trimming moments, it will be seen that:

$(12)(MT1'')\ (T_{tr}) = (X_{KN})\ (R_{KN})$ (C1)

or,

$T_{tr} = [(X_{KN})\ (R_{KN})] / [(12)\ (MT1'')]$ (C2)

or

$R_{KN} = [(12)(MT1'')(T_{tr})] / X_{KN}$ (C3)

where:

T_{tr} = change in trim (ft)

X_{KN} = lever arm between knuckle and LCF (ft)

R_{KN} = knuckle reaction (tons).

APPENDIX D.

COMPUTATION OF MAXIMUM INDIVIDUAL BLOCK LOAD AND MAXIMUM UNIT STRESS AT THE KNUCKLE

997-D.1 GENERAL

997-D.1.1 Methods for determining total knuckle reaction during drydocking with trim have been discussed in Appendix B and Appendix C. The method of estimating individual block loads and timber unit stresses will now be described.

997-D.1.2 In order to simplify the discussion, it will be assumed for the present that the blocks near the knuckle are in contact (butted) and the skeg or keel is as wide as the blocks.

997-D.1.3 For any specific amount of trim remaining, the keel slope is constant regardless of what length is in contact with the blocks. Let the keel slope be expressed as length in feet along the keel for 1 inch rise in keel height, that is:
$S_k = L / (12\ T_{re})$ (D1)
then
$L_k = S_k\ C_{kn}$ (D2)
where:

S_k = keel slope (ft/in)

L = ship length between perpendiculars (ft)

T_{re} = trim remaining (ft)

L_k = length of keel in contact (ft)

C_{KN} = knuckle block compression (in).

997-D.1.4 The unit stress at the aft end of the knuckle block corresponding to the compression, C_{KN} , is obtained from a stress-strain curve for the dock block assemblage. Figure 997-D-1 shows a representative curve.

997-D.2 CALCULATION OF BLOCK LOAD AND UNIT STRESS

997-D.2.1 The steps necessary to find the individual block load and unit stress corresponding to a specific residual trim and total knuckle reaction are:

1. Assume a value for the maximum unit stress at the aft end of the knuckle block (S).
2. Obtain from the stress-strain curve of figure D1 the corresponding compression at the knuckle (C_{KN}).
3. Assuming triangular deformation of the stern block or blocks, obtain from equation D2 the length of keel in contact (L_k).
4. For a triangular loading compute the total knuckle load (reaction), as follows:

R_{KN} = (1/2240) [(1/2 S)(12W_b)(12L_k)] tons (D3)
= .032 SW_b L_k
where:

R_{KN} = knuckle reaction (tons)

S = maximum unit stress at aft end of knuckle block (lb/in^2)

W_b = block width (ft) (4 ft for standard blocks)

L_k = length of keel in contact (ft).

NOTE

It should be emphasized that neither the block deformation nor the block loading will be triangular when the ship is ready to land on the blocks all along the keel. When all or nearly all of the keel is in contact, hull bending may alter the deformation and load pattern radically, particularly for ships with a large percentage of overhang. On the other hand, when only about half of the trim has been removed, at which point the individual block load and the knuckle unit stress reach their peak values, the contact length is only of the order of one to two percent of the length between perpendiculars. Under these conditions, the assumptions of triangular deformation and triangular loading are quite reasonable.

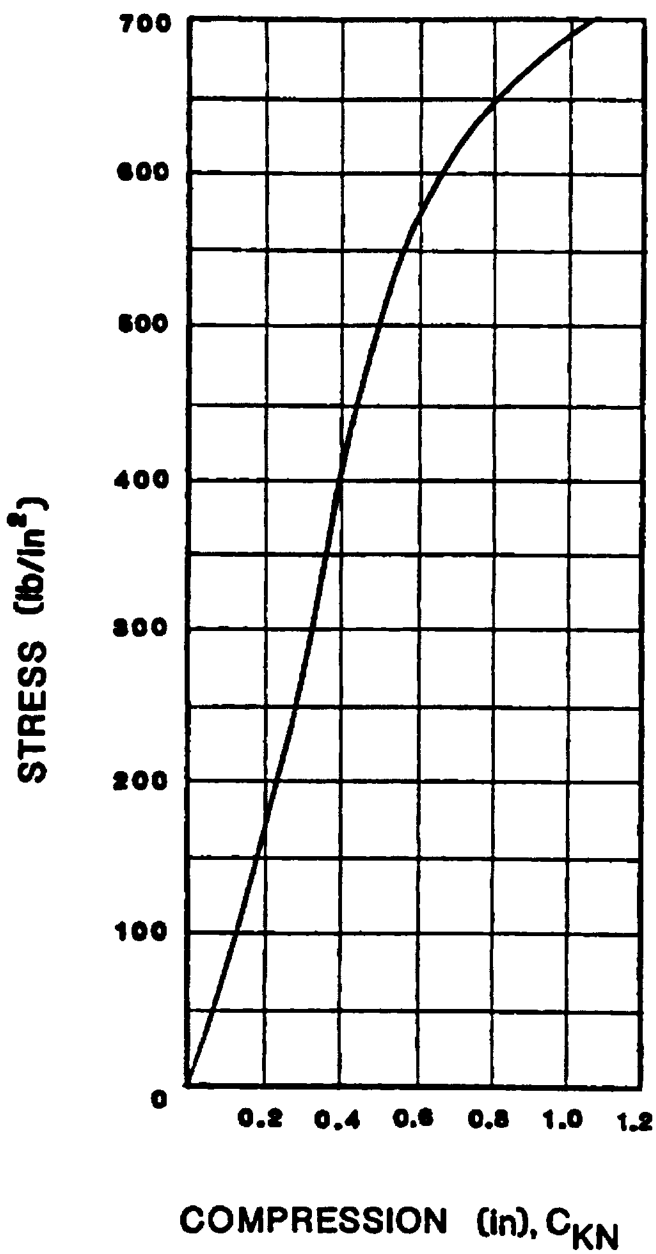


Figure 997-D-1. Stress-Strain Relationships for Typical Dock Block

997-D.2.2 The value of total knuckle load (reaction) obtained from equation (D3) in the first calculation will almost certainly differ somewhat from that obtained by the methods described in Appendix B and Appendix C. If the discrepancy indicates a difference in the stress values of greater than 5 percent, a new value of maximum unit stress should be assumed and the process repeated. With a little experience, the first assumption for unit stress can be so chosen that the true value lies in between, and can readily be determined by interpolation to an accuracy of several percent.

997-D.2.3 It is important to note that, for moderate changes, the maximum knuckle stress varies approximately as the square root of the total knuckle reaction, provided the slope of keel remains unaltered. For example, a 5 percent increase in maximum block stress will also cause essentially the same increase in contact length; consequently, the total reaction will have become $(1.05)^2$ times as great, or approximately 10 percent more.

997-D.3 SPACED BLOCKS NEAR KNUCKLE

997-D.3.1 When the blocks close to the knuckle are spaced, the gross knuckle reaction computed on a triangular stress distribution must be corrected for the absence of block support at each space. These deductions are easily found graphically by plotting the gross contact length and block positions as abscissae and the triangular stress as ordinates, and reading out the mean stress for each space between blocks. The deduction corresponding to each space will then be given by:
Deduction = [1/2240] [mean stress for space, lb/in^2] [12] [space between blocks, ft] [12W_b] tons (D4)

997-D.4 GENERAL REMARKS

997-D.4.1 The calculation outlined in this appendix is most conveniently carried out in a tabular form. Table 997-D-1 and the supporting explanation illustrate this for the FF-1052 (pertinent data on the FF-1052 is given in paragraph 997-A.1). This calculation is shown for an initial trim of 3 feet and is carried out for successive trim decrements of 6 inches, in order to demonstrate the pattern of variations in knuckle unit stress and knuckle block total load. The results are plotted in Figure 997-D-2. This figure shows that the maximum unit stress occurs when 50 percent of the trim has been eliminated and that the maximum total load on the knuckle occurs when 60 to 70 percent of the trim has been removed. Referring again to , starting from an initial trim of 2.5 feet, the maximum unit stress during pumpdown is 205 lb/in^2 (row 9) and the maximum total load during pumpdown in the knuckle block is approximately 133 tons (row 13). For the purpose of this example, the keel blocks are butted, the length of the knuckle block is 42 inches and the block width is 48 inches. The calculations and explanation which support , column by column, follow:

Row 1. T_{tr} = assumed

Row 2. $T_{re} = T_a - T_{tr}$

Row 3. $R_{KN} = (12MT1''T_{tr})/X_{KN}$

Row 4. assume two values

$S_{A_{1,2}}$

Row 5. values corresponding to , from figure 997-D1.

$$C_{KN_{1,2}}$$

$$S_{A_1}$$

Row 6. $S_k = L / 12T_{re}$

Row 7.

$$L_{K_{A_{1,2}}} = (S_{K_A})(C_{KN_{1,2}})$$

Row 8.

$$R_{KN_{1,2}} = \frac{(\frac{1}{2})(144)W_b L_{k_{A_{1,2}}} S_{A_{1,2}}}{2240}$$

Row 9.

$$S = \frac{(R_{KN} - R_{KN_1})S_{A_2} + (R_{KN_2} - R_{KN})S_{A_1}}{R_{KN_2} - R_{KN_1}}$$

Row 10.

$$C_{KN} = \frac{(S - S_{A_1})\ C_{KN_2} + (S_{A_2} - S)\ C_{KN_1}}{S_{A2} - S_{A1}}$$

Row 11. $L_K = (L / T_{re})(C_{KN})$

Row 12. $S_{ave} = (S + [\ (S/L_k)\ (L_k - 42)\ ])\ /\ 2$

$S_{ave} = (S/2)$

Row 13. $R_{kb} = [(S_{ave})(42)(48)] / 2240$

$[(S_{ave})(L_k)(48)] / 2240$

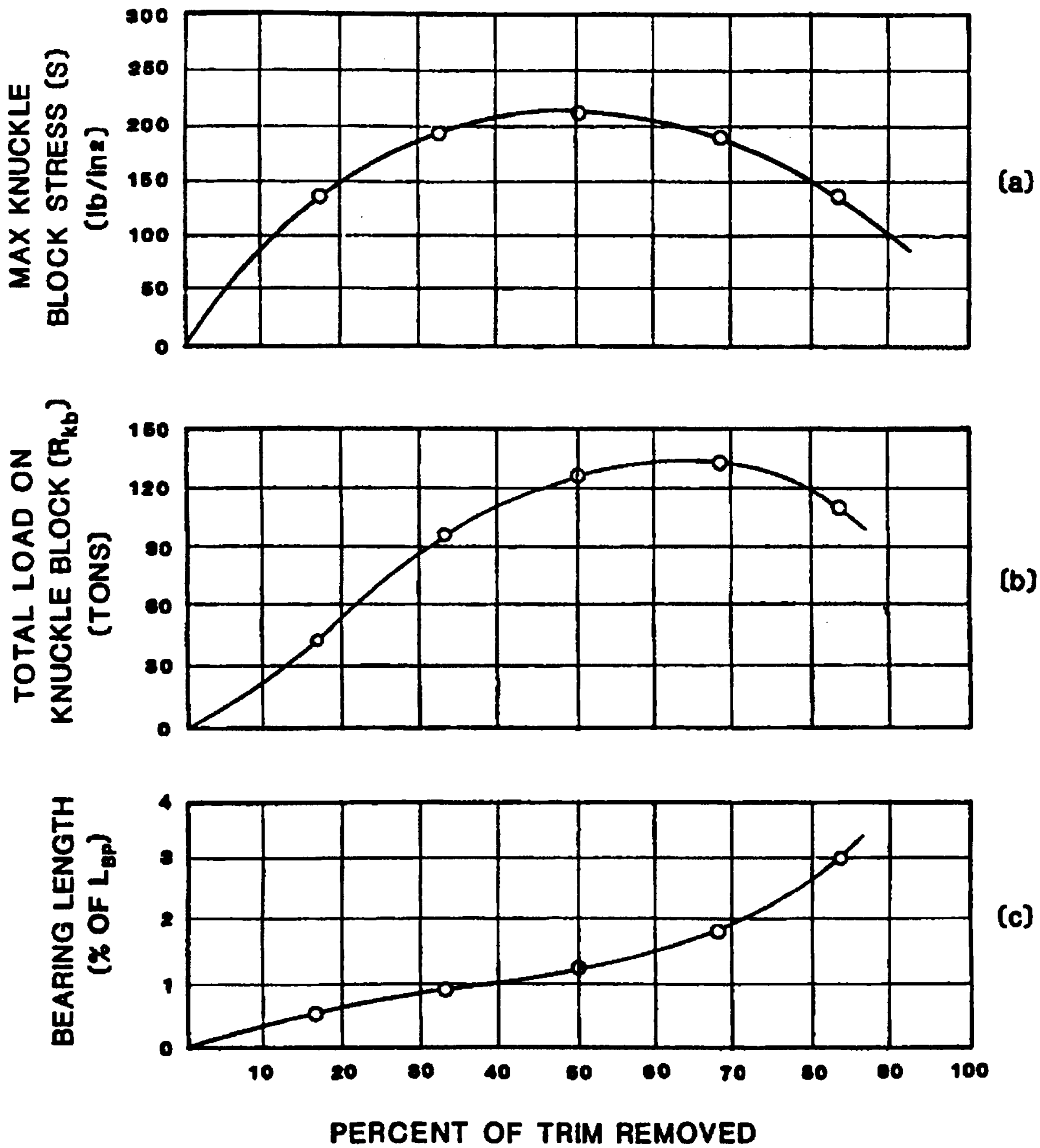
Row 14. Bearing Length = $[(L_k)(100)] / [12(L)]$

Table 997-D-1. TYPICAL CALCULATION FOR BLOCK LOAD AND UNIT STRESS AT KNUCKLE

				Values				
Row No.	**Item Name**	**Item Symbol**	**Item Units**	**Iteration 1**	**Iteration 2**	**Iteration 3**	**Iteration 4**	**Iteration 5**
1	Trim Removed	T_{tr}	ft	0.5	1	1.5	2	2.5

Table 997-D-1. TYPICAL CALCULATION FOR BLOCK LOAD AND UNIT STRESS AT KNUCKLE - Continued

				Values				
Row No.	**Item Name**	**Item Symbol**	**Item Units**	**Iteration 1**	**Iteration 2**	**Iteration 3**	**Iteration 4**	**Iteration 5**
2	Trim Remaining	T_{re}	ft	2.5	2	1.5	1	0.5
3	Knuckle reaction	R_{KN}	tons	47	94	141	187	234
4	Assumed Max. Knuckle Block Stress	S_{A1} S_{A2}	lb/in^2 lb/in^2	100 200	150 200	200 250	190 200	125 175
5	Compression at Aft Edge of Knuckle Block	C_{KN1} C_{KN2}	in in	0.125 0.225	0.190 0.225	0.225 0.290	0.218 0.225	0.175 0.200
6	Keel Slope	S_{KA}	ft/1 inch	13.83	17.29	23.06	34.58	69.17
7	Length of Bearing	$L_{K_{A1}}$ $L_{K_{A2}}$	ft ft	1.73 3.11	3.29 3.89	5.19 6.69	7.54 7.78	12.10 13.83
8	Total Reaction	R_{KN1} R_{KN2}	tons tons	22 80	63 100	133 215	184 200	195 311
9	Maximum Knuckle Block Stress	S	lb/in^2	143	192	205	192	142
10	Knuckle Block Compression	C_{KN}	in	0.17	0.22	0.23	0.22	0.18
11	Length of Bearing	L_k	in	28.22	45.65	63.63	91.30	149.40
12	Average Stress on Knuckle Block	S_{ave}	lb/in^2	71.50	103.68	137.34	147.84	122.04
13	Total Load on Knuckle Block	R_{kb}	tons	43.24	93.31	123.61	133.06	109.84
14	Bearing Length		%	0.6	0.9	1.3	1.8	3
Note: This table applies only to FF-1052 example.								



Note: This table applies only to FF–1052 example.

Figure 997-D-2. FF-1052 Drydocking: Three Foot Trim (Butted Blocks).

997-D.4.2 Inasmuch as the maximum unit stress at the knuckle occurs when half of the trim has been removed, it is possible to express initial allowable trim in terms of maximum unit stress, block stress-strain characteristics, and hull geometry. The derivations for these equations are carried out in appendix E. These equations maintain allowable block loading values of 370 lb/in^2 and 330 tons. The results for various ships are shown in Table 997-2-3. For routine docking problems, these equations will suffice to determine the permissible trim. However, for special docking investigations requiring a knowledge of knuckle stresses and block loads at various phases of the trimming-out process, it will be necessary to use the method discussed in this appendix.

APPENDIX E.

DERIVATION OF ALLOWABLE TRIM FORMULAS

997-E.1 GENERAL

997-E.1.1 This appendix provides the derivation of equations which calculate the maximum trim that a ship may reach during drydocking without overstressing the knuckle block. This allowable trim is a function of the following:

a. Moment to trim 1 inch, MTI″ (ft-tons/in)

b. Length between perpendiculars, L (ft)

c. Distance from knuckle block to longitudinal center of flotation, X_{KN} (ft)

d. Compression of knuckle block, C_{KN} (in)

e. Length of block in contact with ship, L_c (ft).

997-E.1.2 The derivation of the equations for t_a is a function of the following:

a. Knuckle block reaction (R_{KN})

b. Ship/block geometry at point of maximum stress

c. Block configuration (i.e., butted or spaced).

997-E.1.3 Equation C3 of Appendix C provided the knuckle block reaction, restated here:
R_{KN} = (12 MT1″ T_{tr}) / X_{KN} (C3)
where:

R_{KN} = Knuckle block reaction (tons)

T_{tr} = change in trim (ft)

X_{KN} = distance from knuckle block to the LCF (ft).

997-E.1.4 Appendix D shows that the maximum unit stress at the knuckle occurs when approximately one half of the initial trim has been eliminated (i.e., T_{tr} = 1/2 x t_a). To find the knuckle reaction corresponding to this maximum unit stress, equation C3 may be expressed as follows:
R_{KN} = [(12 MT1″) (1/2) (t_a)] / X_{KN}
= [(6 MT1″)t_a] / X_{KN} (E1)
where

t_a = allowable trim (ft)

997-E.1.5 The ship/block geometry at the point of maximum stress, when the trim is equal to one-half of the maximum allowable, is illustrated in Figure 997-E-1. The block size and angle are exaggerated to show various key ship and block characteristics. Figure 997-E-1 (a) shows the ship-block system. Figure 997-E-1 (b) shows

the ship-block geometry and the resulting similar triangle relationship. The relationship between corresponding sides of the similar triangles may be expressed as follows:
$(C_{KN}/12) / L_c = (t_a/2) / L$
where:

12 converts C_{KN} (in) to C_{KN} (ft).

This equation is solved for L_C, and becomes:

$L_c = (C_{KN} L) / (6t_a)$ (E2)

997-E.1.6 Equations E1 and E2 apply to either butted or spaced blocks; however, to find expressions for area and average stress, butted and spaced blocks must be treated separately, as shown in the following sections.

997-E.2 BUTTED BLOCKS

997-E.2.1 For blocks measuring 48 inches athwartships, the loaded area, Ab, of the blocks will be given by:

$A_b = (L_c)(48)(12)$

997-E.2.2 Assuming a triangular stress distribution (average stress = S/2; see Figure 997-E-2), and considering the entire width of the block, the knuckle reaction will be:
$R_{KN} = A_b (S/2)(1/2240 \text{ ton/lb})$
$= (L_c)(48)(12)(S/2)(1/2240)$ (E3)
where:
S = allowable unit stress at aft end of knuckle block (lb/in^2).

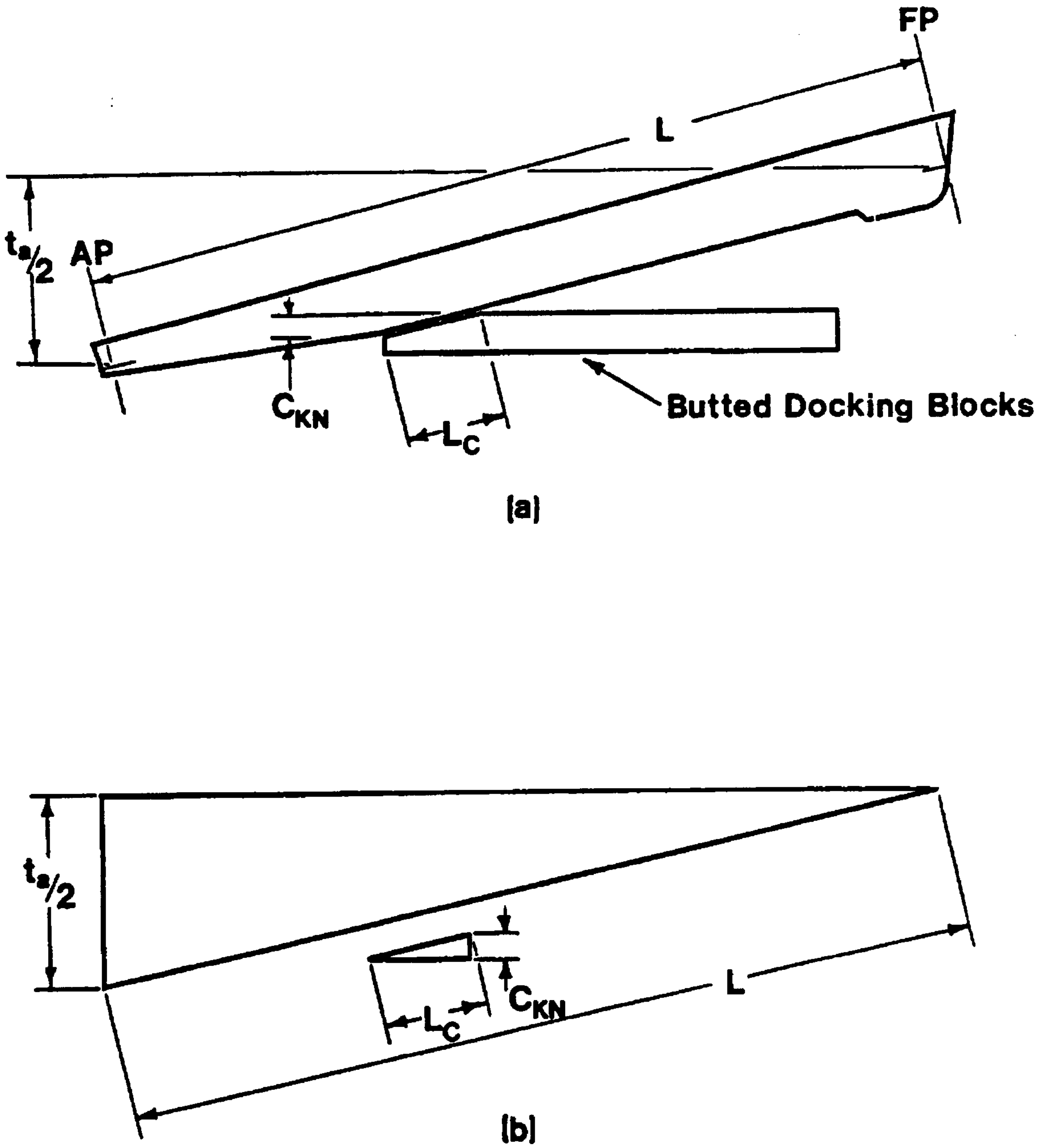


Figure 997-E-1. Geometry When Trim is (t_a /2).

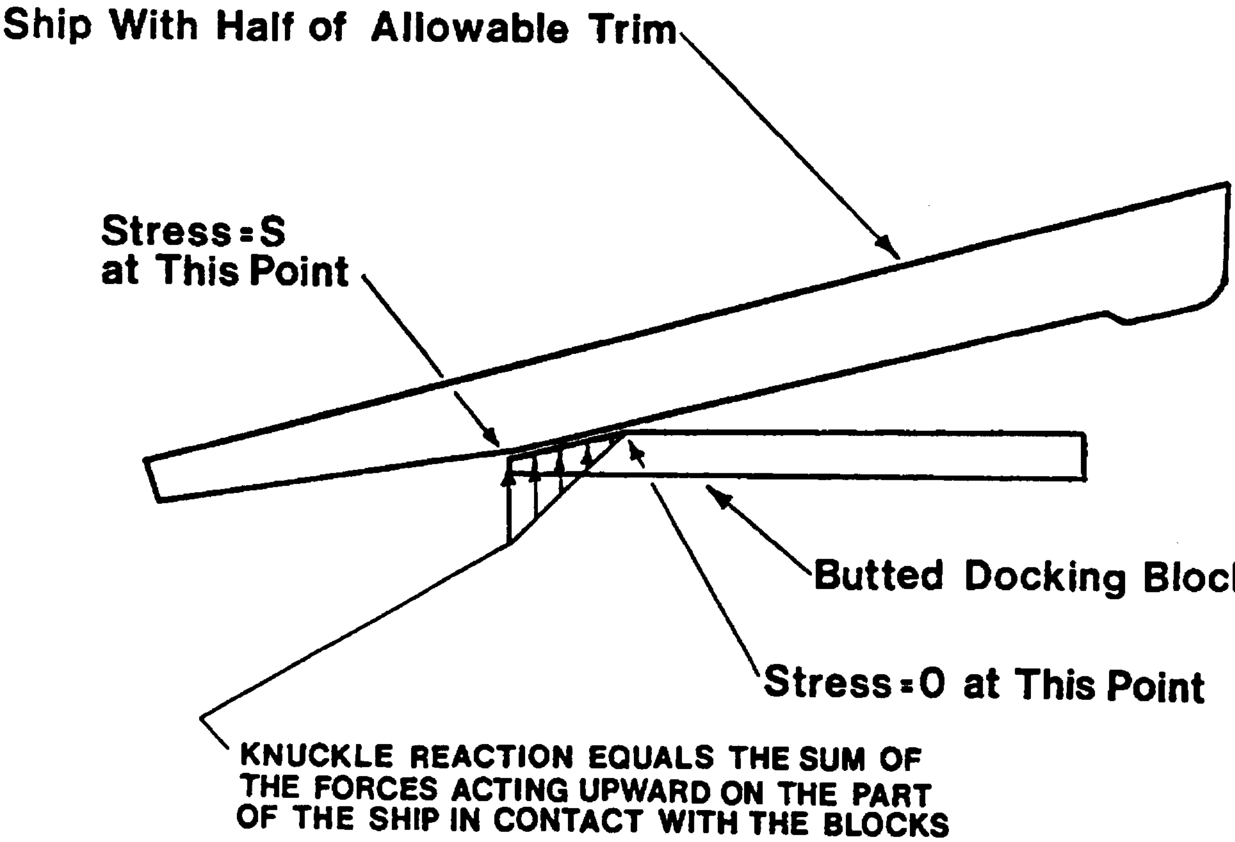


Figure 997-E-2. Knuckle Reaction with Butted Blocks.

997-E.2.3 The allowable trim can then be found by substituting E2 for L_c in equation E3 and setting E1 equal to E2 as follows:

$R_{KN} = [(C_{KN}\ L)/(6t_a\ )]\ (48)(12)(S/2)(1/2240)$

$= (C_{KN}\ LS)/(46.67t_a\ )$ (E2 + E3)

$R_{KN} = [(6MT1'')t_a\ ]\ /\ X_{KN}$

$= (C_{KN}\ LS)\ /\ (46.67t_a\ )$ (E1 = E2)

Solving the second of these two expressions for t_a gives:

$$t_a = \sqrt{\frac{SC_{KN}L}{280}\,\frac{X_{KN}}{MT1''}} \qquad \text{(E4)}$$

Since ($(SC_{KN}\ L)$ / 280) is constant for a given hull and block system:

$$t_a = C\sqrt{\frac{X_{KN}}{MT1''}}\ ft \qquad (E5)$$

which is equation 2-13.

997-E.2.4 With twin skegs (CV 41 class) or with a wide single skeg resting on double width blocks (CV 59 class), the formula becomes:

$$t_a = \sqrt{\frac{S\ C_{KN} L}{140}\ \frac{X_{KN}}{MT1''}}\ ft \qquad (E6)$$

997-E.2.5 An example calculation of allowable trim for ships with standard sized butted blocks is given below.

997-E.2.5.1 Pertinent data for the FF-1052 at full load condition is as follows:

L = 415 ft

Keel width at knuckle = 2.25 ft (assumed for this example)

Single Skeg

X_{KN} = 105 ft

MT1″ = 820 (ft-tons/in.)

Δ = 4255 tons

Calculation of C coefficients:
From Table 997-2-1 (knowing that keel width is 2.25 ft)

C_{KN} = .32

S = 300

$C = \sqrt{[(SC_{KN}\ L)/280]}$ (2-14)

$C = \sqrt{([(300)(.32)(415)]/280)} = 11.93$

$t_a = C\sqrt{(X_{KN}\ /MT1'')}$ (2-13)

$t_a = 11.93\sqrt{(105/820)} = 4.27$ ft.

997-E.2.6 To find the number of blocks bearing, the slope of the keel must be determined. It has been found that the individual block load and unit stress in the timbers will reach a maximum when approximately half of the trim has been removed. Therefore, the value of trim remaining is equal to half of the trim allowable, as stated previously.
$S_k = L\ /\ (12\ T_{re}\ )$ (D1)

T_{re} = 4.27 / 2 = 2.14 ft
S_k = 415 / (12(2.14)) = 16.16 ft/in
$L_k = S_k \, C_{KN}$ (D2)
Length of a single keel block = 42 in

Therefore,
number of blocks bearing = 62.04/42
= 1.48, say 1.5 blocks.

997-E.3 SPACED BLOCKS (SIX FEET CENTER TO CENTER)

997-E.3.1 OVERVIEW. The symbols are the same as in the treatment of butted blocks, except as noted. Three specific and one general case will be considered (Figure 997-E-3 summarizes the results).

997-E.3.2 CASE 1. ONE BLOCK IN CONTACT WITH THE KEEL. Derivation for this case is as follows.
Area (A1) of one block is (42)(48) = 2016 in^2 .
Stress at aft edge of block = S.
For blocks measuring 42 inches (3.5 feet) fore and aft, the stress at the forward edge of the block (S1) may be expressed as follows:

$$S_1 = S\left[\frac{CK_N L}{6t_a} - 3.5\right]\left[\frac{1}{\frac{C_{KN}L}{6t_a}}\right] = S\left[1 - \frac{(3.5)6t_a}{C_{KN}L}\right] = S\left[1 - \frac{21\ t_a}{C_{KN}L}\right] \qquad \text{(E7)}$$

$$S_{ave} = \frac{1}{2}(S + S_1) = \frac{1}{2}\left[\ S + S(1 - \frac{21t_a}{C_{KN}L})\ \right]$$

$$= \frac{S}{2}\ (2 - \frac{21t_a}{C_{KN}L}) \qquad \text{(E8)}$$

$$R_{KN} = A_1 \, S_{ave} \, \frac{1}{2240} \text{ lbs/ton}$$

Therefore,

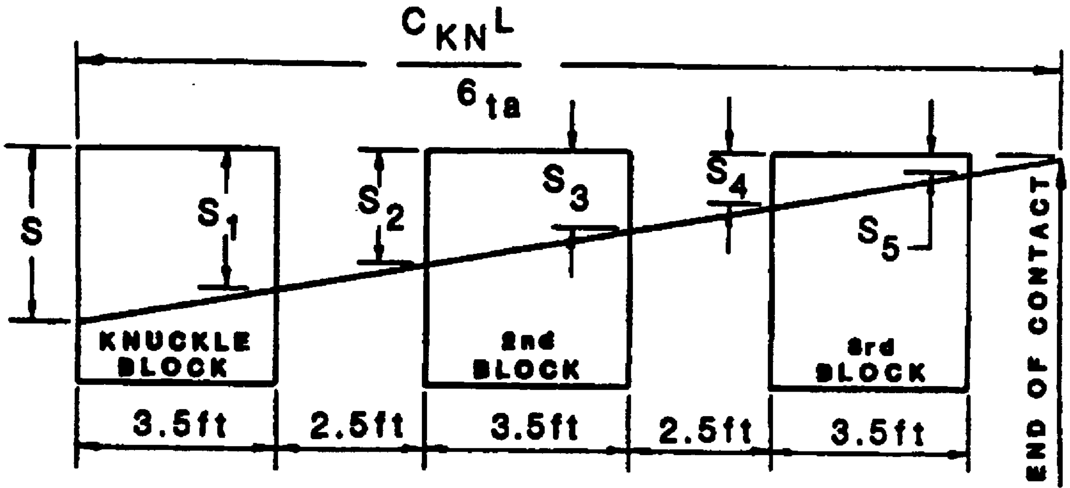
$$\frac{(6MT1")t_a}{X_{KN}} = 2016 \left[\frac{S}{2} \left(2 - \frac{21t_a}{C_{KN}L}\right) \right] \left(\frac{1}{2240}\right) \quad \text{(E9)}$$

Solving for t_a :

$$t_a = \frac{S}{6.67} \; \frac{X_{KN}}{MT1" + \frac{(1.58S)}{C_{KN}L} X_{KN}} \quad \text{(E10)}$$

If terms C_1 and C_2 are defined as:

$$C_1 = \frac{S}{6.67} \text{ and } C_2 = \frac{1.58S}{C_{KN}L} \quad \text{(E11)}$$



S = ALLOWABLE STRESS IN BLOCK

$$S_1 = S\left(1 - \frac{21ta}{C_{KN}L}\right)$$

$$S_2 = S\left(1 - \frac{36ta}{C_{KN}L}\right)$$

$$S_3 = S\left(1 - \frac{57ta}{C_{KN}L}\right)$$

$$S_4 = S\left(1 - \frac{72ta}{C_{KN}L}\right)$$

$$S_5 = S\left(1 - \frac{93ta}{C_{KN}L}\right)$$

Figure 997-E-3. Stress Diagram for Spaced Blocks.

Then, substituting the (E11) terms into equation (E10) results in the expression:
$t_a = C_1 [X_{KN} /(MT1'' + C_2 X_{KN})]$ (E19)
for a given hull and block.

997-E.3.3 CASE 2. TWO BLOCKS IN CONTACT WITH THE KEEL. Derivation for this case is as follows.
S = Stress at aft edge of aft (knuckle) block
S_1 = Stress at forward edge of aft (knuckle) block
S_2 = Stress at aft edge of second block
S_3 = Stress at forward edge of second block
$S_{ave} = (1/4) (S + S_1 + S_2 + S_3)$ (E13)
, as in derivation of equation E7

$$S_1 = S\left[1 - \frac{(3.5)(6t_a)}{C_{KN}L}\right]$$

$$S_2 = S \left[\frac{C_{KN}L}{6t_a} - (3.5 + 2.5) \right] \left[\frac{1}{\frac{C_{KN}L}{(6t_a)}} \right]$$

$= S (1 - [(36t_a) / (C_{KN} L)])$ (E14)

$$S_3 = S \left[\frac{C_{KN}L}{6t_a} - (3.5 + 2.5 + 3.5) \right] \left[\frac{1}{\frac{C_{KN}L}{(6t_a)}} \right]$$

$= S (1-[(57t_a) / (C_{KN} L)])$ (E15)

$$S_{ave} = \frac{1}{4} \Big(\underbrace{\left[S + S \left(1 - \frac{21t_a}{C_{KN}L}\right)\right]}_{\text{knuckle block}} + \underbrace{\left[S \left(1 - \frac{36t_a}{C_{KN}L}\right) + S\left(1 - \frac{57t_a}{C_{KN}L}\right)\right]}_{\text{second block}} \Big) \qquad \text{(E16)}$$

$S_{ave} = S (1 - [(28.5t_a) / (C_{KN} L)])$ (E17)
Area of two blocks = (2)(2016) = 4032 in^2 .
Since R_{KN} = (Area)(S_{ave}), equations E1 and E17 can be combined to give:

$$\frac{(6\ MT1")t_a}{X_{KN}} = 4032S \left(1 - \frac{28.5t_a}{C_{KN}L}\right) \left(\frac{1}{2240}\right) \qquad \text{(E18)}$$

Solving for t_a :

$$t_a = \left[\frac{2S}{6.67}\right]\left[\frac{X_{KN}}{MT1" + \frac{8.55S}{C_{KN}L}X_{KN}}\right] \tag{E19}$$

Proceeding as before, and defining C_1 and C_2 :
$C_1 = 2S / 6.67$ and $C_2 = 8.55S / C_{KN} L$ (E20)
Then

$$t_a = C_1 \left(\frac{X_{KN}}{MT1" + C_2X_{KN}}\right) \text{ for a given hull and blocks.} \tag{E21}$$

For two blocks with twin skegs:
Area = (2)(4302) = 8064 in^2

$$t_a = \frac{4S}{6.67} \quad \frac{X_{KN}}{MT1" + \frac{17.10S}{C_{KN}L}X_{KN}} \tag{E22}$$

in this case
$C_1 = 4S / 6.67$ and $C_2 = 17.10S / C_{KN} L$ (E23)

997-E.3.4 CASE 3. THREE BLOCKS IN CONTACT WITH THE KEEL. Derivation for this case is as follows.
Area = (3)(2016) = 6048 in^2
S_4 = Stress at aft edge of third block from knuckle
S_5 = Stress at forward edge of third block from knuckle

$$S_4 = S\left[\frac{C_{KN}L}{6t_a} - (3.5 + 2.5 + 3.5 + 2.5)\right]\left[\frac{1}{\frac{C_{KN}L}{6t_a}}\right]$$

$= S(1 - [\,(72t_a\,) / (C_{KN}\,L)\,])$

$$S_5 = S\left[\frac{C_{KN}L}{6t_a} - (3.5 + 2.5 + 3.5 + 2.5 + 3.5)\right]\left[\frac{1}{\frac{C_{KN}L}{6t_a}}\right] \qquad \text{(E24)}$$

= $S(1 - [\,(93t_a\,) / (C_{KN}\ L)\,])$
$S_{ave} = (1/6)(S + S_1 + S_2 + S_3 + S_4 + S_5\ )$

$$= \frac{1}{6}\left(\overbrace{\left[S+S\left(1-\frac{21t_a}{C_{KN}L}\right)\right]}^{\text{knuckle block}}+\overbrace{\left[S\left(1-\frac{36t_a}{C_{KN}L}\right)+S\left(1-\frac{57t_a}{C_{KN}L}\right)\right]}^{\text{second block}}+\overbrace{\left[S\left(1-\frac{72t_a}{\frac{C_{KN}L}{6t_a}}\right)+S\left(1-\frac{93t_a}{C_{KN}L}\right)\right]}^{\text{third block}}\right)$$

= $S(\ 1 - [\,(46.5t_a\,) / (C_{KN}\ L)\,]\ )$ (E25)
Since R_{KN} = (Area)(S_{ave}), equations E1 and E25 can be combined to give:

$$\frac{(6\ \mathrm{MT1''})t_a}{X_{KN}} = 6048S\left(1 - \frac{46.5t_a}{C_{KN}L}\right)\left(\frac{1}{2240}\right)$$

Solving for t_a :

$$t_a = \frac{3S}{6.67}\left[\frac{X_{KN}}{\mathrm{MT1''} + \frac{20.93S}{C_{KN}L}X_{KN}}\right] \qquad \text{(E26)}$$

In this case:
$C_1 = 3S / 6.67$ and $C_2 = (20.93S / C_{KN}\ L)$ (E27)
For double width blocks (CV 59 class), area = (2)(6048) = 12,096 in^2 .

$$t_a = \frac{6S}{6.67}\left[\frac{X_{KN}}{MT1'' + \frac{41.86S}{C_{KN}L}X_{KN}}\right] \quad (E28)$$

In this case:
$C_1 = 6S / 6.67$ and $C_2 = 41.86S / C_{KN} L$ (E29)

NOTE

The equations for spaced blocks are derived for total contact of one, two, or three blocks. If the contact between keel and block ends within a block rather than within a space between blocks, the block in partial contact may either be included as a whole block or omitted entirely in choosing the proper equation. Whichever equation is used, the allowable trim calculated will be slightly less than by a trial and error solution using the precise contact length.

997-E.3.4.1 An example calculation of allowable trim and number of blocks bearing for ships with standard sized spaced blocks is given below. Pertinent data for the CV-59 class in full load condition is as follows:
L = 990 ft
Keel width at knuckle = 8 ft (Double Blocks)
X_{KN} = 314.4 ft
MT1″ = 12770 (ft-tons/in)
Δ = 78600 tons
From table 997-4
C_{KN} = .38
S = 370
From table 997-7
$C_1 = 6S / 6.67$ and $C_2 = 41.86S / C_{KN} L$ (E29)
and inserting the specific values this example
$C_1 = 6(370) / 6.67 = 332.83$
$C_2 = [(41.86(370)) / (.38(990))]41.17$
combining equations (E28) and (E29)
$t_a = C_1 [X_{KN} /(MT1''+C_2 X_{KN})]$
and inserting the values calculated above for C_1 and C_2
$t_a = 332.83 [314.4 / ([12770]+[(41.17)(314.4)])] = 4.07$
$t_{re} = 4.07/2 = 2.04$
$S_K = 990 / [12(2.04)] = 40.44$ (D1)
$L_K = (40.44)(.38) = 15.37$ ft or 184.41 in (D2)
Length of keel blocks = 42 in
Spacing between blocks = 72 in (center to center) - 42 in = 30 in
Thus, each block plus space is (42 in + 30 in) or 72 in, so in this example the number of blocks bearing will be:
Number of blocks bearing = 184.41 / 72
= 2.56 blocks.

997-E.3.5 CASE 4. GENERAL CASE. The general case for any constant block spacing and block length is as follows:

$$t_a = \left[\frac{nA_1S}{13440}\right]\left[\frac{X_{KN}}{MT1" + \frac{nA_1S\ X_{KN}\ [en + h\ (n - 1)]}{4480\ C_{KN}L}}\right] \quad (E30)$$

Where

n = Number of blocks in contact with keel

A = Area of one keel block (in^2) (for twin skegs or wide single skeg supported by double blocks use area of two blocks)

e = Fore and aft length of block (ft)

h = Clear space between blocks (ft).

997-E.3.5.1 All other variables are as previously defined. This equation is for use with non-standard block spacing and/or block size. With proper substitution of terms it will reduce to one of the allowable trim equations given above in appendix E.

997-E.3.5.2 For butted blocks the substitution of h = 0
[n - [(C_{KN} L)/(6t_a e)]] will reduce equation E30 to E5.

997-E.3.5.3 Using differential calculus, equation E30 can be differentiated with respect to n to derive an expression for the value of n at which trim is maximum (i.e., t_a). This derivation is not carried out here, but the result is:

$$n = \sqrt{\frac{4480\ C_{KN}\ LMT1"}{A_1\ SX_{KN}\ (e+h)}} \quad (E31)$$

Thus, for any constant block spacing and block length, equation (E31) can be used to calculate n. Then equation (E30) is used to calculate t_a .

APPENDIX F.

COMPUTATION OF MAXIMUM ALLOWABLE TRIM, FOR LANDING ON BLOCKS WHICH HAVE SOFT CAPS THAT YIELD

997-F.1 GENERAL

997-F.1.1 Methods for determining total knuckle reaction during drydocking with trim have been discussed in Appendix B and Appendix C. The method of determining maximum allowable trim and associated block loading is described in this appendix, for the circumstances under which the soft cap blocks yield or crush.

997-F.1.2 When the keel of a ship just starts to bear on a soft wood cap block, the pressure between the keel and the block increases as the block is compressed. When this pressure reaches a certain level (about 370 lb/in^2) the pressure remains approximately constant as the wood continues to yield. If the reduction in thickness is not greater than 25 percent of its original thickness, the wood will not be seriously damaged, and it will spring back to about its original thickness when the load is removed.

997-F.1.3 For ships with keels narrower than the docking blocks, there is a concentration of loading on the cap block directly under the keel. A limited amount of yielding of these cap blocks can be anticipated when docking a ship with trim. This compressibility of soft wood causes the load required to remove the trim to be distributed over a greater length of blocks.

997-F.2 ALLOWABLE COMPRESSION

997-F.2.1 The maximum allowable compression consists of two parts: the compression which occurs in the entire block before the cap pieces yield, and the additional compression of the cap pieces. The allowable additional compression in the cap pieces is 1/2 inch if they are 2 inches thick or thicker. If less than 2 inches thick, the allowable additional compression is 25 percent of original thickness. The maximum allowable compression is expressed as follows:

$$C_{KN} = C_y + C_a$$

where:

C_{KN} = maximum allowable compression (in)

C_y = compression which occurs due to stress before soft wood yields (from Figure 997-D-1) (in)

C_a = allowable additional compression (in)

t_c = thickness of the cap (in)

997-F.2.1.1 To find the compression which occurs before soft wood in the cap yields, Figure 997-D-1 should be used unless specific information about the particular block is available.

997-F.2.1.2 To find the allowable pressure at the aft end of the knuckle block, the pressure at which soft wood yields, without permanent deformation, must be averaged over the width of the block.
$P_{KN} = P_s [(W_k) / W_b]$
where

P_{KN} = pressure at aft end of knuckle block, averaged over entire width of block.

P_s = pressure at which soft wood yields without permanent deformation

W_k = width of keel

W_b = width of blocks

997-F.2.1.3 To illustrate this limitation, suppose a ship with a skeg 1 foot wide is to be docked with trim; that the yielding stress (P_s) in the cap blocks is 370 lb/in^2; that the cap blocks are at least 2 inches thick; and that the stress-strain relationship shown in Figure 997-D-1 is applicable.

$W_b = 4$ ft

$W_k = 1$ ft

$P_{KN} = (370)(1/4) = 92.5$ lb/in^2 (F1)

$C_y = 0.11$ in

$C_a = 0.5$ in

$C_{KN} = C_y + C_a = 0.11 + 0.5 = 0.51$ in

997-F.2.1.4 It should be noted that the following limitations apply whether or not cap blocks yield:

a. Ship must be stable

b. Maximum load per block is 330 tons

c. Maximum pressure averaged over width of block is 370 lb/in^2

997-F.2.1.5 To find P_{KN}, 370 lb/in^2 should be used for P_s unless specific information about the particular blocks is available. If the value of P_{KN} calculated from equation F1 is greater than 370 lb/in^2 this appendix is not applicable. The calculations should then be made in accordance with Appendix D.

997-F.3 KNUCKLE REACTION

997-F.3.1 BUTTED KEEL BLOCKS. In order to simplify the explanation, it will be assumed for the present that the blocks near the knuckle are in contact (butted). The total knuckle load can then be found from equations D1 and D2, and modifications of equation D3:
$S_k = L / (12\, T_{re})$ (equation D1 restated) (F2)
$L_k = S_k C_{KN}$ (equation D2 restated) (F3)

$$R_{KN} = \frac{1}{2240} [(P_{KN})(12W_b) (12) (L_k - \frac{C_y L_k}{2\ C_a})] \quad (F4)$$

where:

S_k = Keel Slope (ft/inch)

T_{re} = trim remaining (ft)

L = length between perpendiculars (ft)

L_k = length of keel contact with blocks (ft)

R_{KN} = knuckle reaction (tons).

The value of total knuckle load (reaction obtained from the formula above) will almost certainly differ somewhat from that obtained by the methods described in Appendix B and Appendix C. If the discrepancy is large, a new value of trim should be assumed, and the total knuckle reaction should again be calculated by each of the two methods. Ordinarily the maximum allowable value of trim can be found by interpolation.

997-F.3.2 SPACED BLOCKS NEAR THE KNUCKLE. When the blocks close to the knuckle are spaced, the gross knuckle reaction computed above must be corrected for the absence of block support at each space. The deduction corresponding to each space is given by equation D4 (restated here and labelled equation F5):
Deduction = [1/2240][mean stress for space, lb/in^2][12][space between blocks, ft][12W_b] tons (F5)
As an example, the maximum trim will be computed at which an FF 1052 class destroyer can be docked at full load displacement, for which:

L = 415 ft

MT1″ = 820 ft-tons/in

X_{KN} = 104.7 ft.

For the first try, assume the trim on entering dry dock is 4 feet between perpendiculars. The loading on the blocks will be most severe when the water is partially pumped out, so that the remaining trim is one-half the original trim [(1/2)(4) = 2 feet] and the change in trim (T_{tr}) is (4 - 2 = 2 feet). From equation C3:
R_{KN} = [(12)(MT1″)(T_{tr})] / X_{KN} (C3)
= [(12)(820)(2)]/104.7 = 188 tons.
Noting that (T_{re} is (4 - 2 = 2 feet), S_{yk} may be calculated from equation F2:
S_k = 415 / [(12)(2)] = 17.29 ft/in
From equation F3 (assuming C_{KN} = 0.67):
L_k = (17.29)(0.67) = 11.58 ft
In figure 1 this value of L_k is shown relative to the spaced keel blocks. Not that the forward extremity of L_k is located in a space between blocks.
From equation F4 (assuming the values: P_{KN} = 150, C_a = 0.67, and C_y = 0.17):

$$R_{KN} = \frac{1}{2240}\left[(150)\ (12)(4)(12)\ \left(11.58 - \frac{0.17\ (11.58)}{(2)(0.67)}\right)\right]$$

= 390 tons.

997-F.3.2.1 Keel blocks are 3.5 feet long, spaced 6 feet center to center. The entire length of the aftermost block and part of the next one are compressed by the skeg (see Figure 997-F-1). A diagram for stress versus longitudinal location can be developed using Figure 997-F-2. As shown in this figure, the stress remains constant until the compression is reduced to C_y , then the stress is proportional to reduction in compression, or the length from the point of zero stress.

$L_{CS} = L_k - [(C_y\ L_k)/C_{KN}]$

$P(C_y) = (P_{KN}/C_{y\ max})\ (C_y)\ (L)$

where:

L_{CS} = length of constant stress from the knuckle forward

C_y max = C_y

C_y (L) = compression as a function of the distance from the knuckle

$P(C_y)$ = stress at variable compression C_y (L)

For this example:

L_{CS} = 11.58 - (.17/.67)(11.58) = 8.64

P(end of block) = 150(2.09/2.94) = 106.6.

997-F.3.2.2 For convenience in making the deduction for the space between blocks, the area to be deducted (in the diagram) is divided into a rectangular part and a triangular part.

Part	**Mean Stress (lb/in^2)**	**Length (feet)**	**(Mean Stress) x (length)**
Rectangular	150	2.50	375
Triangular	106.63/2 = 53.32	2.09	111.44
		TOTAL DEDUCTION	486.44

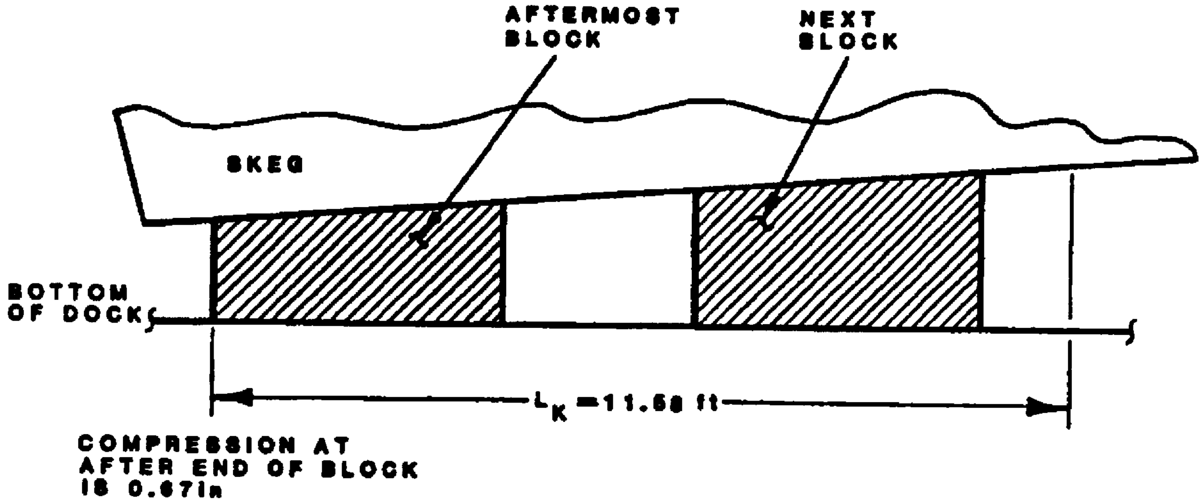
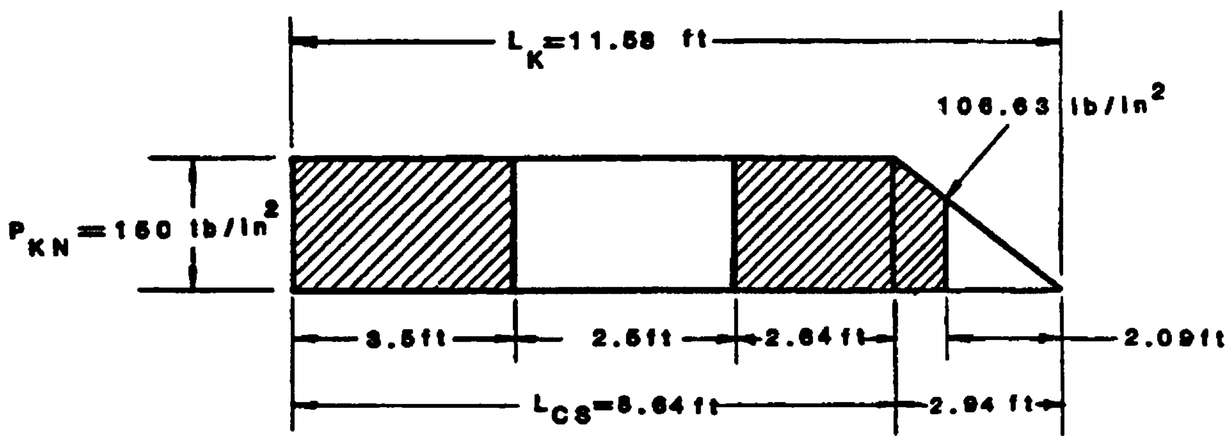


Figure 997-F-1. Spaced Keel Blocks Example - Compression in Aft Two Blocks.



NOTE: THE CROSS-HATCHED PORTIONS OF THE DIAGRAM REPRESENT KEEL BLOCKS, AND THE BLANK PORTIONS REPRESENT SPACES BETWEEN KEEL BLOCKS.

Figure 997-F-2. Diagram of Stress Plotted Against Longitudinal Location.

From equation D4:
Deduction = (1/2240) [(486.44)(12)(12)(4)] = 125.08 tons
Reaction = 390 - 125.08 = 264.92 tons

This calculated reaction of 264.92 tons is 76.92 tons larger than the figure of 188 tons, calculated from the moment-to-trim. Therefore, the allowable trim is more than 4 feet.

997-F.3.2.3 For the next trial, the initial trim will be assumed to be 5 feet (maximum stress is at the reduction of one-half the trim, therefore for the FF-1052, 2'- 6″, trim between perpendiculars). Using equation C3 which is based on moment-to-trim one inch:
R_{KN} = [(12)(820)(2.5)] / 104.7 = 235 tons
From equation D1:
S_k = 415 / (12)(2.5) = 13.8 ft/in
From equaiton F3:
L_k = (13.8)(0.67) = 9.25 ft
L_{CS} = 9.25 - (.17/.67)(9.25) = 6.9 ft
From equation F4:
Total knuckle load (assuming butted blocks)

$$R_{KN} = \frac{1}{2240}(150)(12)(4)(12)\left[9.25 - \frac{0.17}{(2)(0.67)}(9.25)\right]$$

= 312 tons
From equation D4:
Deduction = (1/2240) [(150)(12)(2.50)(12)(4)] = 96 tons
Reaction = 312 - 96 = 216 tons.

This calculated reaction of 216 tons is 19 tons smaller than the reaction of 235 tons, calculated from the moment to trim one inch. Therefore, the allowable trim is less than 5 feet, and it can only be found by interpolation, as follows:

Initial Trim (feet)	**Reaction Calculation from Moment to Trim (tons)**	**Reaction Calculation from Compression of Blocks (tons)**	**Difference**
4	188	265	-77
5	235	216	+19

Allowable trim = 4 + [77/(77+19)] = 4.80 feet between perpendiculars.

This interpolation may also be performed graphically, as shown in Figure 997-F-3.

997-F.3.2.4 It is also necessary to check the stability. This has been done for the example above, in accordance with Appendix A, and found to be satisfactory. The calculations are not shown here.

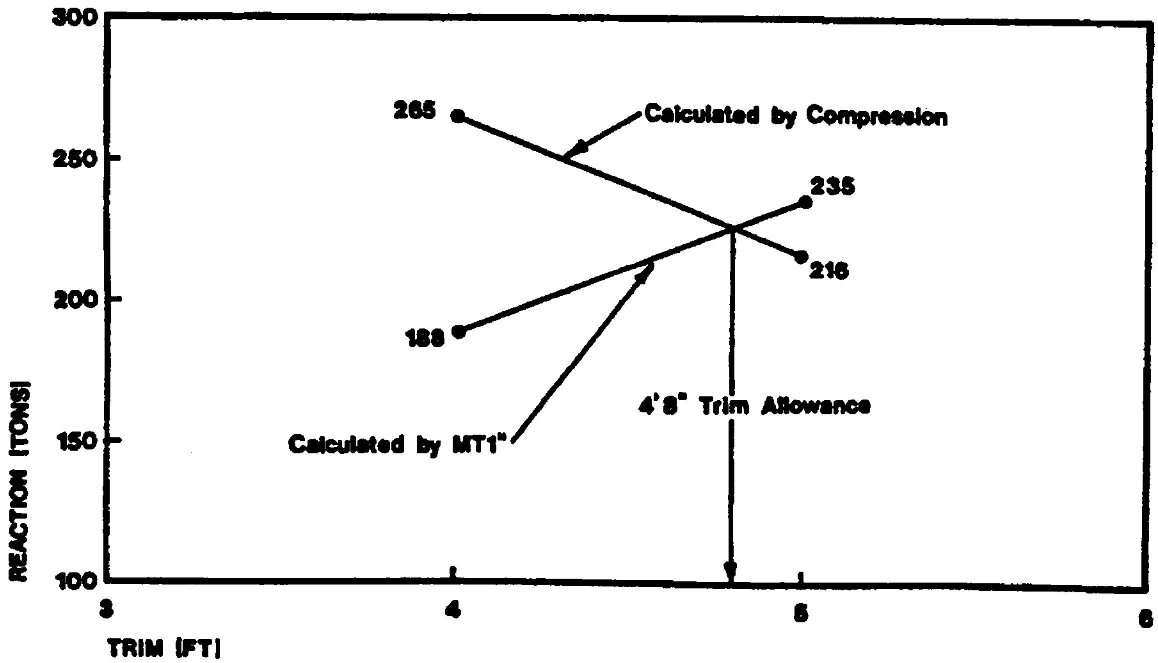


Figure 997-F-3. Determination of Allowable Trim by Graphical Interpolation.

APPENDIX G.

NUMERICAL EXAMPLES OF SIDE BLOCK AND SHORING TO RESIST EARTHQUAKE OR HURRICANE FORCES

997-G.1 OVERVIEW

997-G.1.1 This appendix presents examples for calculating the required number of side blocks and shoring to resist earthquake or hurricane forces. Note that for these calculations, S_p (strength at the proportional limit of the block material) is taken to be 800 lb/in^2 . This value is significantly higher than the 370 lb/in^2 used for other applications in this document, and is presently under review. However, the 800 lb/in^2 is presently considered reasonable for these calculations because: (1) past experience indicates that 800 lb/in^2 is a practical and safe limit, and (2) permanent deformations (but not failures) are acceptable in a one-time loading of earthquake or hurricane forces, where ship survival and not block/shoring reusability is the issue.

997-G.2 EARTHQUAKE FORCES, USE OF SIDE BLOCKS WITHOUT SHORES

997-G.2.1 Refer to Figure 997-G-1. The pertinent data for the FF-1052 is:
Ship Dead Load (W) = 4255.56 tons
Center of gravity above keel (KG) = 17.45 ft
Horizontal earthquake acceleration = 0.2g
Effective area of contact for each bilge block (A_2) = 18 in (athwartship) x 28 in (longitudinally) = 504 in^2
Seismic overturning moment (M_s) = (.20)(4255.56)(17.45)(2240) = 33,268,265 ft-lb

For these seismic calculations the proportional limit of the side block cap (S_p) is taken to be 800 lb/in^2 for Douglas fir. The number of side blocks (N_2) required on each side to resist seismic overturning moment is found

by using equation 2-3:
$N_2 = M_s / (A_2\ S_p\ L_2)$ (G1)
where
L_2 = Average moment arm of side block reaction (ft) (see figure G1) = 10.3 ft.
N_2 = 33,268,265 / [(504)(800)(10.3)] = 8.01

997-G.2.2 The additional load due to the dead load of the ship (W) must be added to this. A good assumption is to consider that side blocks take 15% of W and that one half of this is taken per side so that the load on one set of side blocks (DL_s) is:
DL_s = (4255.56)(0.15)(1/2) = 319 tons
Area required for dead load = DL_s / S_p = (319(2240)) / 800
= 893 in^2
Area required for seismic forces = $N_2\ A_2$ = (8.01)(504)
= 4037 in^2
Total area required = 893 + 4037 = 4930 in^2
Number of side blocks required:
$N_2 = Area/A_2$ = 4930/504 = 9.78
Use 10 stable side blocks per side, each with 504 square inches of effective contact area.

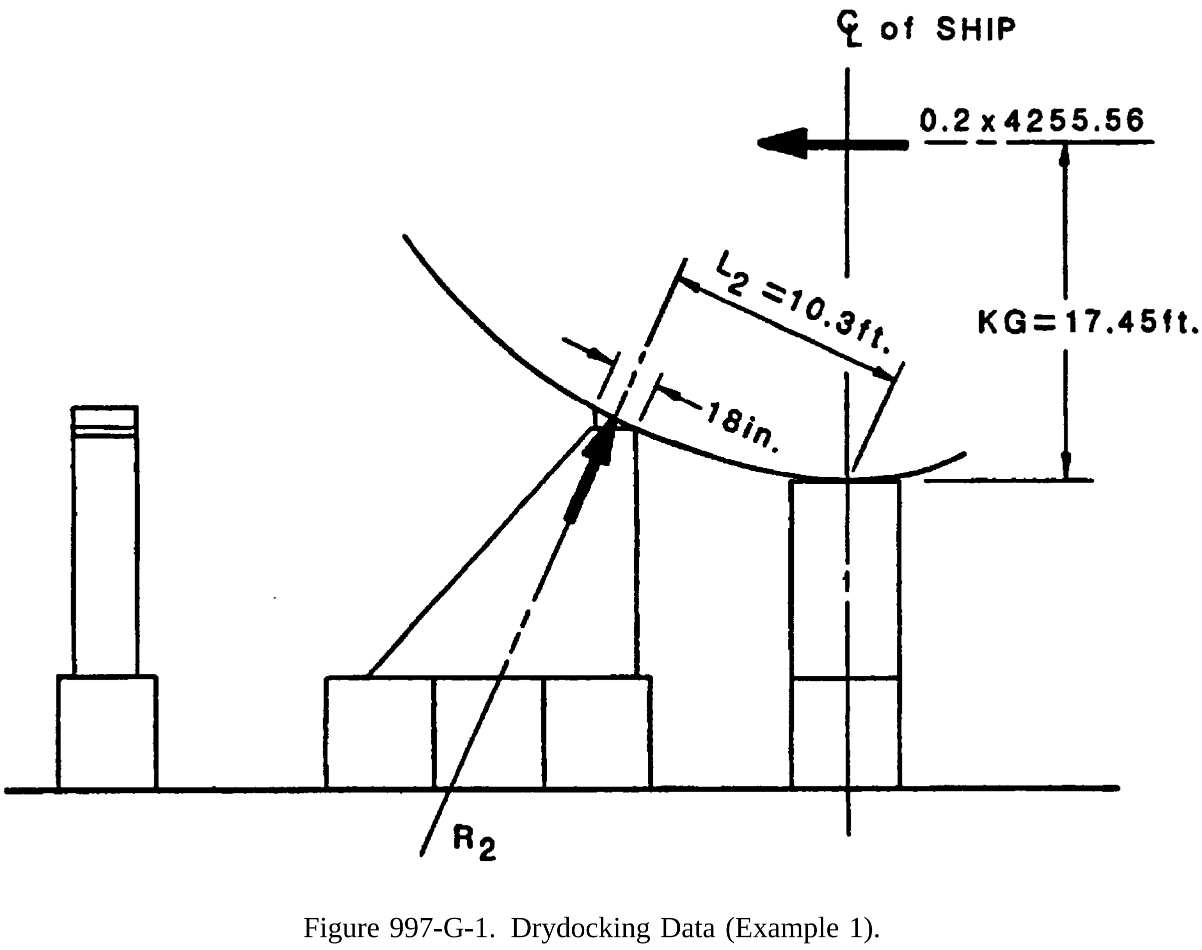


Figure 997-G-1. Drydocking Data (Example 1).

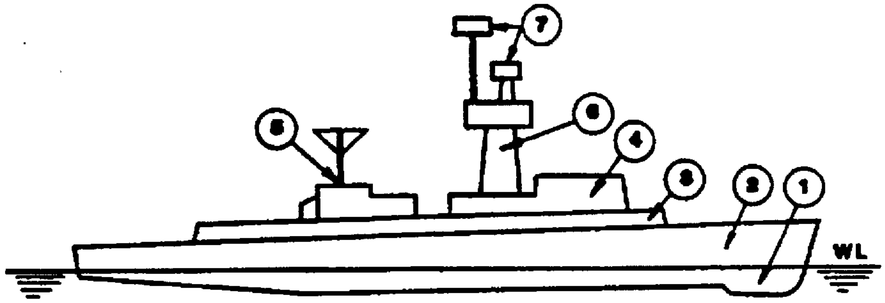
997-G.2.3 The transverse stability of individual side blocks is essential and depends on overall block height and the hull shape. In the example shown, it is necessary to utilize pier blocks, adequately fastened together to serve as a side block base. These side blocks shall be of a pier type construction, such that the resultant force (R2) (normal to shell at point of tangency) shall fall within the middle one-third of all horizontal layers of blocking.

997-G.3 HURRICANE FORCES, USE OF SIDE BLOCKS WITHOUT SHORES

997-G.3.1 Basic data for FF-1052 and side blocks is the same as in section 997-G.1, plus:
Wind velocity = 100 knots
Hurricane overturning moment (M_h) = 18,694,476 ft-lbs (See Figure 997-G-2 for development of M_h)
Number of side blocks (N_2) required on each side to resist hurricane overturning moment:
$N_2 = M_h / (A_2 S_p L_2)$ (G2)
= 18,694,436 / [504(800)(10.3)] = 4.50

997-G.3.2 The additional load due to the dead load of the ship (W), must be added to this. As in section 997-G.1 we assume the side blocks take 15% of W and that one half of this is taken per side so that the load on one set of side blocks (DL_s) is:
DL_s = (4255.56)(0.15)(1/2) = 319 tons
Area required for dead load = DL_s / S_p
= [(319)2240]/800 = 893 in^2 (G3)
Area required for hurricane forces = $N_2 A_2$
= (4.50)(504) = 2268 in^2
Total area required = 893 + 2268 = 3161 in^2
The number of blocks required:
$N_2 = Area/A_2$ = 3161/504 = 6.27

Use 7 stable side blocks per side, each with 504 square inches of effective contact area. As in section 997-G.1 the transverse stability at side block is essential.



SKETCH OF FF 1052 SHOWING LOCATION OF AREAS
USED IN CALCULATIONS

CALCULATION OF HURRICANE OVERTURNING MOMENT

AREA ITEM	AREA (ft^2)		UNIT FORCE * (lb/ft^2)		FORCE (lb)		LEVER ARM (ft)		MOMENT (ft-lb)
(1) BELOW DWL	5025	x	40	=	201,000	x	7.5	=	1,507,500
(2) ABOVE DWL	7980	x	40	=	319,200	x	22.4	=	7,150,080
(3) ABOVE DWL	2176	x	40	=	87,040	x	31.3	=	2,724,352
(4) PILOT HSE ETC	1562	x	40	=	62,480	x	49.8	=	3,111,504
(5) FUEL STA	739	x	40	=	29,560	x	43.8	=	1,294,728
(6) BILLBOARD & SMOKE PIPE	712	x	40	=	28,480	x	77.2	=	2,198,656
(7) ANTENNA	182	x	40	=	7,280	x	97.2	=	707,616
							TOTAL MOMENT		18,694,476

* HURRICANE FORCE AT 100 KNOTS = $(.004\ lb/ft^2kt^2)(100\ kt)^2$
$40\ lb/ft^2$

Figure 997-G-2. Hurricane Overturning Moment (Example 2).

997-G.4 USE OF SPUR SHORES IN CONJUNCTION WITH SIDE BLOCKS

997-G.4.1 Spur shores may be used in combination with side blocks to resist overturning moments due to either seismic or hurricane forces. Consider the case of seismic loading in paragraph 997-G.2. Suppose it was not possible to place 10 stable side blocks under the ship. Then spur shores could be used in place of the missing side blocks. Refer to Figure 997-G-3. Basic data for FF-1052 and side blocks is the same as in paragraph 997-G.2. Assume that only 8 of the required 10 side blocks could be placed under the FF-1052. Assume the shores are 10 inch by 10 inch Douglas fir with an average length of 19 feet. Then equations 2-4 and 2-5 defining the loads in the shores and the side blocks are:

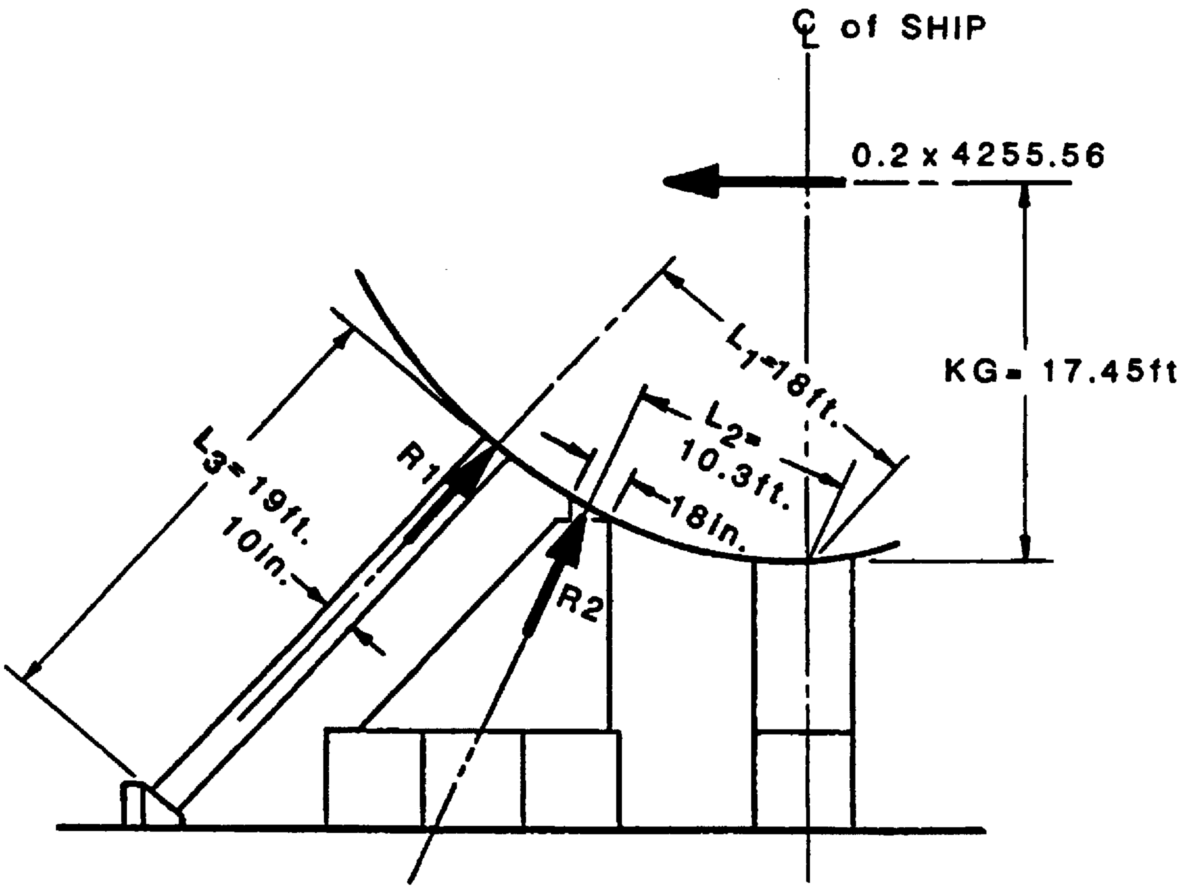


Figure 997-G-3. Drydocking Data (Example 2).

$R_1 = (M_S K_1 L_1) / (L_1^2 N_1 K_1 + L_2^2 N_2 K_2)$
(Reaction in each spur shore) (G4)
$R_2 = (M_S K_2 L_2) / (L_1^2 N_1 K_1 + L_2^2 N_2 K_2)$
(Reaction in each side shore) (G5)
where

M_S = 33,268,265 ft-lb

L_1 = 18 ft

L_2 = 10.3 ft

K_1 = Spring constant for shores
= $(A_S E_1) / (12L_3) = [(10)(10)(1.6 \times 10^6)] / 12(19) = 701{,}754$ lb/in

K_2 = Spring constant for side block (assumed)
= 200,000 lb/in

A_s = Cross sectional area of spur shore,
= (10)(10) = 100 in^2

E_1 = Modulus of elasticity of spur shore
= 1.6×10^6 lb/in^2 (for Douglas fir)

N_1 = Number of spur shores

N_2 = Number of side blocks
= 8

997-G.4.2 Spur shores must not buckle under load. To check their stability, equation (G6) is used to find the safe column stress, S_c :

$$S_c = C\left[1 - (1/3)\left[\frac{(L_3)^4}{Kd}\right]\right] \qquad \text{(G6)}$$

C = Proportional limit of Douglas fir parallel to the grain
= 3000 lb/in^2
L_3 = 19 ft
$K = 1.11\sqrt{(E_1/C)} = 1.11\sqrt{[(1.6 \times 10^6)/3000]} = 25.63$
$E_1 = 1.6 \times 10^6$ lb/in^2
d = Minimum dimension of the spur shore cross section = 10 inches
So:

$$S_c = 3000\ [\ 1-(1/3)\ (\frac{(19)(12)}{25.63(10)})^4\ ]$$

= 2371 lb/in^2
Therefore the spur shore reaction, R_1 , must be equal to or less than:
$R_1 \leq S_c A_s$
$\leq 2371\ (100) = 237{,}100$ lbs
Now we can rearrange equation (G4) and solve for N_1 :
$N_1 = (M_S K_1 L_1 - R_1 L_2{}^2 N_2 K_2) / (R_1 L_1{}^2 K_1)$
$= [\ (33{,}268{,}265)(701{,}754)(18) - (237{,}100)(10.3)^2\ (8)(200{,}000)\ ] / [\ (237{,}100)(18)^2\ (701{,}754)\ ]$
= 7.05

Therefore, use 8 spur shores per side in conjunction with 8 side blocks per side instead of the 10 side blocks as determined in paragraph 997-G.2. A similar analysis can be performed for the use of spur shores to resist hurricane forces.

APPENDIX H.

STANDARDIZATION OF DOCKING DRAWINGS

997-H.1 GENERAL

997-H.1.1 Ships of all classes are constructed by a great number of builders and are docked many times in many locations during their operating lifetimes. In the interest of safety and economy, NAVSEA has sought to obtain standardization of the size, composition, spacing, and arrangement of docking blocks. Similarly a program of general standardization of docking drawings was inaugurated and is being implemented on a continuing basis. There are three types of docking drawings:

a. Class Guidance Docking Drawings

b. Individual Standardized Docking Drawings

c. Group Docking Drawings.

997-H.1.2 Provisions for preparation and distribution of all types of docking drawings for ship construction and conversion projects are included in appropriate ship specifications, and costs are chargeable to funds allocated for the projects involved.

997-H.1.3 Modification and correction of existing docking drawings are the responsibility of the Planning Yard and are funded by the Ships Program Manager (SPM), in accordance with the provisions of NAVSEA SL720-AA-MAN-010, Fleet Modernization Program (FMP) Management and Operations Manual .

997-H.2 DOCKING DRAWING TYPES

997-H.2.1 CLASS GUIDANCE DOCKING DRAWINGS. It is the responsibility of the design activity for the first ship to prepare Class Guidance Docking Drawings for:

a. New classes of ships or service craft to be constructed

b. Conversions of existing ships or service craft where the hull form or length is modified

c. Conversions of existing ships or service craft where the hull form is not modified but no docking drawing exists in the format of NAVSEA Drawing 803-5184105 (Submarines) or NAVSEA Drawing 803-5184106 (Surface Ships), as applicable

All Class Guidance Docking Drawings shall be submitted to NAVSEA for approval. Upon receiving NAVSEA approval, two prints and one reproducible copy of the approved drawings shall be forwarded to NAVSEA. In addition, the Supervisor shall forward a 35-mm microfilm aperture card of the approved drawing to each activity building or converting follow ships of the class, to be used in the preparation of the Individual Standardized Docking Drawing for each ship. The drawings shall be prepared in the format of NAVSEA Drawing 803-5184105 (Submarines) or NAVSEA Drawing 803-5184106 (Surface Ships), as applicable, and MIL-STD-100 and then transferred to 35-mm microfilm aperture cards in the format of MIL-M-38761/2.

997-H.2.2 INDIVIDUAL STANDARDIZED DOCKING DRAWINGS. The Individual Standardized Docking Drawing is applicable to only one ship. It is the responsibility of the individual shipbuilder to prepare an Individual Standardized Docking Drawing for each individual ship built, or each individual ship converted. The drawing shall be prepared directly from the 35-mm microfilm aperture card. It shall be revised to suit the individual offsets, appendages, openings, and other details of the particular ship.

997-H.2.2.1 In cases where a single ship is being converted, but no change is made in hull form and the existing docking drawing is in the format of NAVSEA Drawing 803-5184105 (Submarines) or 803-5184106 (Surface Ships), as applicable, no new drawing need be prepared. It is only necessary to update the existing drawing to make it compatible with the modifications.

997-H.2.2.2 Responsibility for preparation of Individual Standardized Docking Drawings for all ships requiring them but not yet having them is defined as follows:

a. For ships being docked at naval shipyards, the Naval Shipyard Commanders are requested to have the block heights and other appropriate data lifted for preparation of the drawing. The Naval Shipyard Commanders are further requested to have drawings prepared from data forwarded from Commanding Officers and Officers in Charge of other naval activities or from SUPSHIPS.

b. For ships being docked at naval facilities other than naval shipyards, the Commanding Officer or Officer in Charge of the naval facility is requested to have the block heights and other appropriate data lifted and forwarded to the applicable planning yard with the request that the proper drawing be prepared.

c. For ships being docked in private shipyards, the SUPSHIPS Representatives are requested to have the block heights and other appropriate data lifted and forwarded to the applicable planning yard with the request that the proper drawing be prepared.

997-H.2.2.3 Upon completion of a new drawing or modification of an existing drawing, distribution shall be made as shown in Table 997-H-1, except that in the case of nuclear powered ships, the docking drawing shall be held in the custody of U.S. military representatives and passed to foreign addresses only when required for the actual docking of a ship.

997-H.2.3 GROUP DOCKING DRAWINGS. Group Docking Drawings are applicable to whole groups of ships, such as various types of landing ships and service craft. They are prepared to standardize the blocking arrangement of a number of ships or craft of the same type or class in those cases where hull lines are the same, docking problems are not usually critical, or where variations such as appendages and openings within the class are not extensive.

997-H.2.3.1 It is the responsibility of the design activity for the first ship or craft to prepare the Group Docking Drawing for the particular design involved. The drawing is prepared directly from a copy of the approved Class Guidance Docking Drawing by the contractor preparing the design for the first ship or craft being built. The blank title block shall be completed and the drawing made applicable to the ships or craft being built by the contractor preparing the drawing or carrying out the construction. Cognizant naval authorities shall ensure that subsequent ships or craft constructed to a particular design are added to the list of applicability of the appropriate Group Docking Drawing.

997-H.2.3.2 The following is a listing of ship types or craft for which group docking drawings are required:

a. LSM

b. All service craft except YAG and floating dry docks capable of self-docking

997-H.2.3.3 Upon completion of a new drawing or the modification of an existing drawing, the Group Docking Drawing shall be distributed to the addresses listed in Table 997-H-1. The first addressee, Commanding Officer of Ship, pertains to the Officer in Charge of those ships receiving the modifications which necessitated the revision of, or addition to, the Group Docking Drawing.

997-H.3 RESPONSIBILITY FOR CORRECTION OF DRAWINGS

997-H.3.1 When a ship is docked at a naval shipyard and modifications are made to the ship that in any way affect the docking of the ship or in any way affect the information contained on the docking drawing, it is the responsibility of the naval shipyard to obtain the original docking drawing from the planning yard for modification. After the original drawing has been modified, a blueprint, aperture card, or vandyke of the drawing shall be distributed to the addressees listed in Table 997-H-1 and the original returned to the planning yard for retention.

997-H.3.2 When a ship is docked at a naval facility other than a naval shipyard, or in a private shipyard, and modifications such as mentioned above are accomplished, it is the responsibility of the Commanding Officer or Officer in Charge of the naval facility, or the SUPSHIPS Representative for ships docked in private shipyards under whose cognizance the work is being accomplished, to ensure that adequate information concerning the modifications is forwarded to the appropriate planning yard. The planning yard shall then make the necessary modifications to the docking drawing and distribute copies thereof. The planning yard may, at its discretion, provide the shipyard with a reproducible copy of the docking drawing, in lieu of the original, to be marked up and returned. The planning yard will then correct the original in accordance with the marked-up copy and make distribution as above.

997-H.3.3 As an exception to the requirements of the preceding paragraph, the naval facility or private shipyard may undertake the correction of the docking drawing subject to an agreement with the appropriate planning yard that such action is advantageous.

997-H.3.4 It is the responsibility of all activities accomplishing alterations or modifications to a ship which affect the docking of that ship to furnish a marked-up copy of the docking drawing to the Commanding Officer of the ship prior to departure. This procedure will preclude the possibility of damage during subsequent dockings made prior to the receipt of the corrected docking drawing.

Table 997-H-1. DOCKING DRAWING DISTRIBUTION LIST

ADDRESSEE	TYPE OF COPY	NO. OF COPIES
NAVSEA 07Q21	T-2	1
PMS 303 (for Mine Warfare Craft)	NR	1
PMS 325 (for Patrol Coastal Ship)	NR	1
PMS 335 (for Cruisers, Destroyers [DD 963 and DD 993], Frigates [FFG 7])	NR	1
PMS 335 (for Amphibious, Auxiliaries and Service Craft	R	1
PMS 393 (for SSN)	T-2	1
PMS 396 (for SSBN)	T-2	1
PMS 400 (for DDG 51)	T-2	1
COMSUBLANT (for SSN, SSBN, AS, ASR, AFDM, ARDM, ARD)	T-2	1

Table 997-H-1. DOCKING DRAWING DISTRIBUTION LIST - Continued

ADDRESSEE	TYPE OF COPY	NO. OF COPIES
COMSUBPAC (for SSN, SSBN, AS, ASR, AFDM, ARDM)	T-2	1
All Naval Shipyards	R	1 ea.
Portsmouth NSY (Code 202.2)	T-1, T-3	1,1
SUBASE PEARL (Code 7211) for SUBPAC ships)	T-2	1
Planning Yard for Ships and Submarines	O	1
SUPSHIP Groton (for SSN and SSBN) Newport News (for SSN and SSBN) San Diego (except SSN and SSBN)	R R R	1 1 1
NAVMATDATASYSGRU	T-2	1
NAVSHIPREFAC (for PACFLT Ships) Guam Yokosuka (except SSN and SSBN)	R NR	1 1
COMMANDER-IN-CHIEF U.S. NAVY EUROPE (N43) (for LANTFLT SHIP)	R	1
Type Commander (for lead ship of new construction class)	NR	1
COMMANDER Fleet Activities Sasebo (for PACFLT Ships)	NR	1
Cognizant Tenders (for SSN and SSBN)	NR	1
NAVSUBSUPPFAC NLON (for LANTFLT Submarines)	T-2	1
TRIREFFAC Bangor (for PACFLT SSN and SSBN Class)	T-2	1
TRIREFFAC KINGS BAY (for SUBLANT SSN/SSBN)	T-2	1
AFDL-6 (for PC AND MHC)	R	1
AFDM-6 (for PACFLT Submarines except for SSN 21 and SSBN Class)	R	1
AFDM-7 (for all ships up to and including Cruisers)	R	1
AFDM-10 (for LANTFLT Submarines except for SSN 21 and SSBN Class)	R	1
AFDM-14 (for all ships up to and including Cruisers)	R	1
ARD-5 (for all LANTFLT Submarines except for SSN 688 and SSBN Class)	R	1
ARDM-1 (for all LANTFLT Submarines except for SSN 21 and SSBN Class)	R	1
ARDM-4 (for all LANTFLT Submarines except for SSN 21 and SSBN Class)	R	1
ARDM-5 (for all PACFLT Submarines except for SSN 21 and SSBN Class)	R	1
Applicable Submarine	NR T-2	1 1
Applicable Ship	NR	1
Service Squadron 6 (COMSERVFORSIXTHFLT) (for LANTFLT Ships)	NR	1
Military Sealift Command (for ship assigned)	Note 3	

Notes:

1. For inactive ships, one copy (NR) shall be sent to the appropriate Commanding Officer, Naval Inactive Ship Maintenance Facility, with instructions to place the copy in the ship's records aboard the ship.
2. Letters, forwarding revised docking drawing, shall indicate that distribution of prints has been, or will be, made as specified herein.
3. Drawings for ships assigned to the Military Sealift Command are to be distributed in accordance with COMSCINST 9000.1A.
4. Type of Copy
   NR : Non-reproducible

O : Original tracings or master artwork for drawings
R : Reproducible
T-1 : Type I Class 1 Microfilm (aperture card in accordance with MIL-M-38761/2; Microfilm and Tabulating Cards used for recording Engineering Drawings and Associated Data and MIL-STD-804 Series; Formats and Coding of Aperture, Copy, and Tabulating Cards for Engineering Data-Reproduction System)
T-2 : Type II Class 2 microfilm (DIAZO aperture card in accordance with MIL-M-38761/2 and MIL-STD-804 Series)
T-3 : Engineering Data Tabulating Card per figure 1 of MIL-M-38761/2.

5. This table is based on information contained in SL720-AA-MAN-010, Fleet Modernization Program Management and Operations Manual, which contains the most up-to-date listing.

997-H.4 DRAWING CONTENT AND FORMAT

997-H.4.1 All docking drawings, regardless of type, shall contain in general the same type of information, tailored to the class, group, or individual ship involved. General information to be included on all docking drawings is as follows:

a. A plan view of the ship and the blocking arrangement

b. A profile of the ship supported on the pier keel blocks

c. Sections, as required, to illustrate the transverse blocking arrangement, especially in cases where high blocking is required and stability in dock is a consideration

d. Location of keel blocks in all three docking positions

e. Location of side blocks in all three docking positions

f. Location of bitts and chocks on profile view

g. Location of underwater appendages on both profile and plan views

h. Frame spacing of ship on profile view

i. Indication of major transverse bulkheads on profile view

j. Notes on the profile view, in the vicinity of sonar domes, rudders, secondary propulsion units, and similar removable appendages, specifying the clearance below the bottom of the keel required for their removal

k. Notes on the profile view indicating the clearance required beyond the stern reference point for removal of the shaft(s)

l. For submarines, a dimension from the stern reference point to a fixed item always visible above the waterline, such as the upper rudder, if visible, or fairwater

m. Table of critical dimensions

n. Table of displacements and other properties for docking

o. Trim table for propeller clearances

p. Table of block bearing areas and pressures

q. List of openings in the shell below the design waterline, together with locations

r. Tables of offsets for side blocks and keel blocks, as required

s. General notes

t. Any other information considered to be of aid in docking the ship.

997-H.4.2 Class Guidance Docking Drawings shall have two title blocks affixed. One shall be left blank and one shall be completed. The blank title block is included to facilitate the preparation of Individual Standardized Docking Drawings for follow ships of the class and Group Docking Drawings.

997-H.4.3 To establish guidance as to satisfactory format for the preparation of docking drawings, NAVSEA has designated NAVSEA Drawing 8035184105 (Submarines) and NAVSEA Drawing 803-5184106 (Surface Ships) as the master guidance drawings. The formats of these drawings shall be followed to the maximum extent possible.

997-H.4.4 All activities preparing or modifying docking drawings for nuclear powered ships are cautioned not to include any information concerning the nuclear propulsion plant on the docking drawings. Specifically, the labeling of hull penetrations to identify them with the nuclear propulsion plant, and the use of phantom lines and dimensions revealing the internal structure and arrangement of the nuclear propulsion plant, shall be omitted. All activities are directed to remove, if existing, the above information when existing nuclear ship docking drawings are revised for other reasons and in any case before the drawings are microfilmed.

997-H.5 WAIVERS TO DOCKING DRAWINGS

997-H.5.1 Requests for waivers to the format or requirements of docking drawings shall be addressed to Commander, Naval Sea Systems Command, Washington, D.C. 20362-5101, Attention SEA 55Y1X.

APPENDIX I.

DEFINITIONS

997-I.1 DEFINITIONS

Base block - The portion of a docking block which does not include a soft cap. (See Figure 997-I-1, Figure 997-I-2 and Figure 997-I-5).

Batten - A small board or strip of wood or metal used to connect timbers. (See Figure 997-I-1)

Bilge/side block - Docking block used to support a ship in way of the bilge strakes or elsewhere outboard of the ship's longitudinal centerline. (See Figure 997-I-4, Figure 997-I-5 and Figure 997-I-6)

Bracing - Structural material that serves to strengthen and support side blocks. (See Figure 997-I-6)

Butting - Placing independent blocks in contact with one another to form a continuous row of blocks. (See Figure 997-I-3)

Cribbing - Horizontal layers (timber or steel) used to tie two or more otherwise independent block columns together. (See Figure 997-I-2 and Figure 997-I-5)

Crush layer - A layer of softwood, placed between layers of hardwood, which is expected to compress in areas of extreme local keel block loading.

Docking block - Any of several types of individual structures used with others to support a ship in drydock. Generally, they are a concrete/wood composite. (See Figure 997-I-1)

Dog - A staple-like steel clip used to connect adjacent pieces of timber. (See Figure 997-I-1)

Extra-high build - Column of blocks which is 8 feet 6 inches or greater in height.

Hauling block - A keel or bilge/side block that can be moved into position during the docking evolution. (See Figure 997-I-6)

High build - Column of blocks in excess of 6 feet in height but below 8 feet 6 inches in height.

Keel block - A docking block placed under the keel of a ship. (See Figure 997-I-2 and Figure 997-I-3)

Knuckle block - Usually the keel block farthest aft, but occasionally farthest forward, that takes the initial and maximum load when docking a trimmed ship.

Navy composite docking block - A docking block 42″ x 48″ composed of concrete and wood. (See Figure 997-I-1)

Pyramided side block - Base blocks which are stacked on top of each other in pyramid fashion in both the transverse and fore and aft directions. (See Figure 997-I-4)

Side block height - Distance from bottom of the side block to the top of the highest corner of the soft cap.

Side block length - Transverse dimension of the side block in reference to the docked ship's keel.

Side block width - Fore and aft dimension of the side block in reference to the docked ship's keel.

Soft cap - A pad of soft wood that is placed on top of the base block which deforms as necessary to prevent local overstressing of the docked ship or block. (See Figure 997-I-1)

Spur shore - A spar between the dock floor and the hull of the docked ship to provide lateral support to the docked ship.

Ton - The weight unit used interchangeably with long ton (LT) in the field of naval architecture and equal to 2,240 pounds.

Wale shore - A spar between the wall of a dock and the side of the docked ship to provide lateral support to the docked ship.

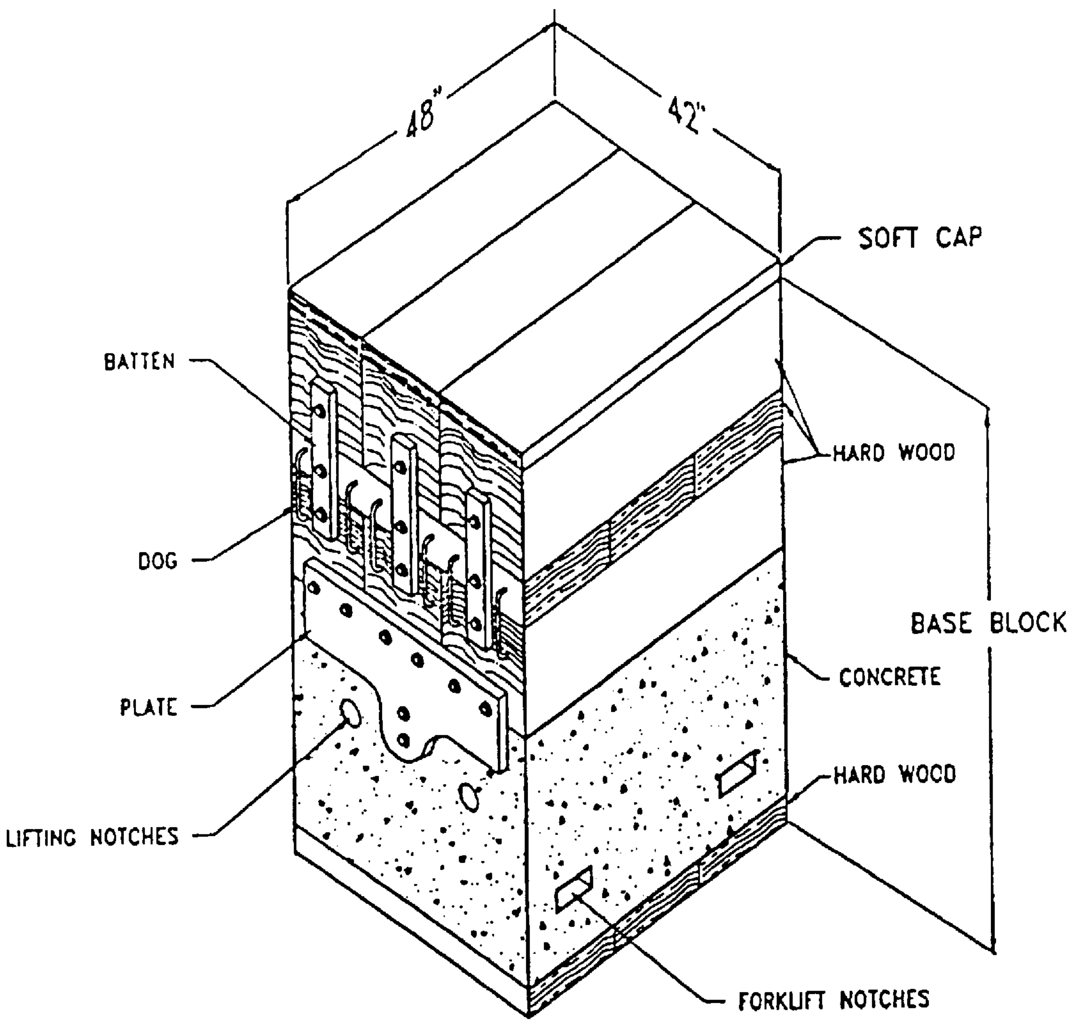


Figure 997-I-1. Navy Composite Docking Block

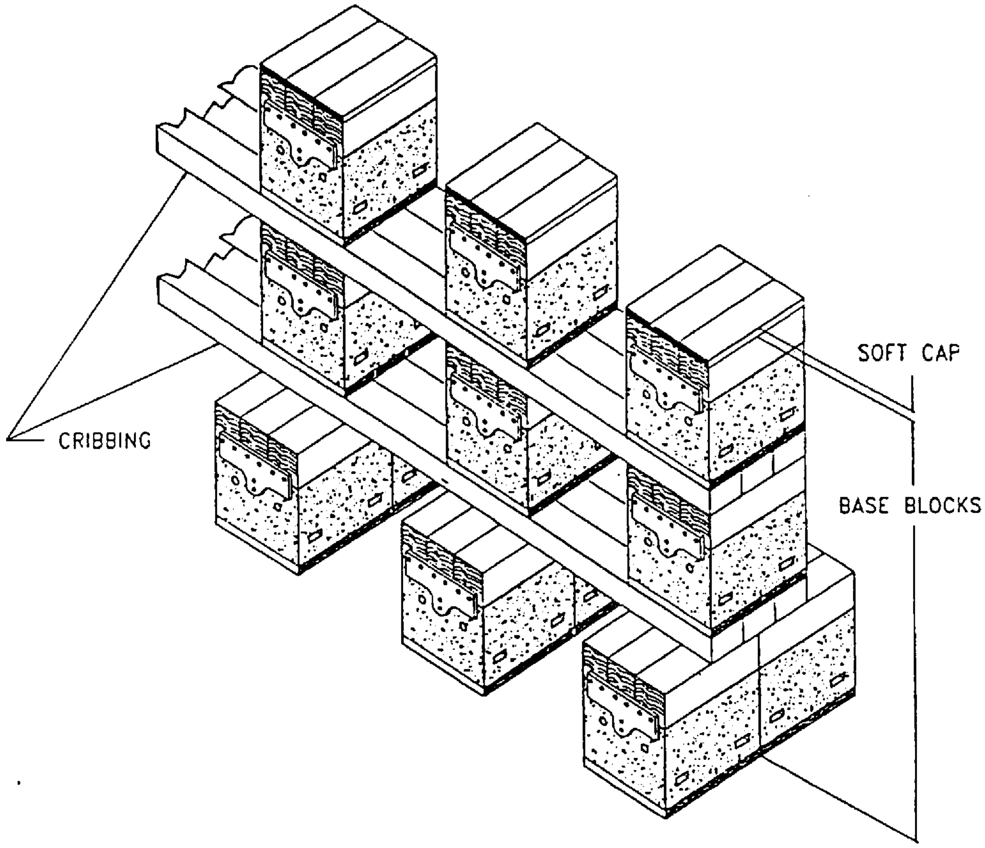


Figure 997-I-2. Cribbed Keel Blocks

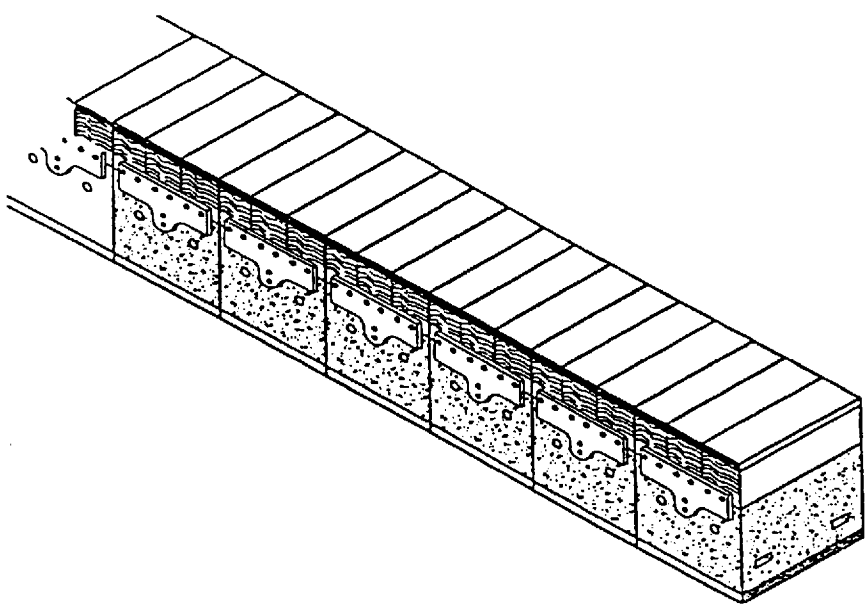


Figure 997-I-3. Butted Keel Blocks

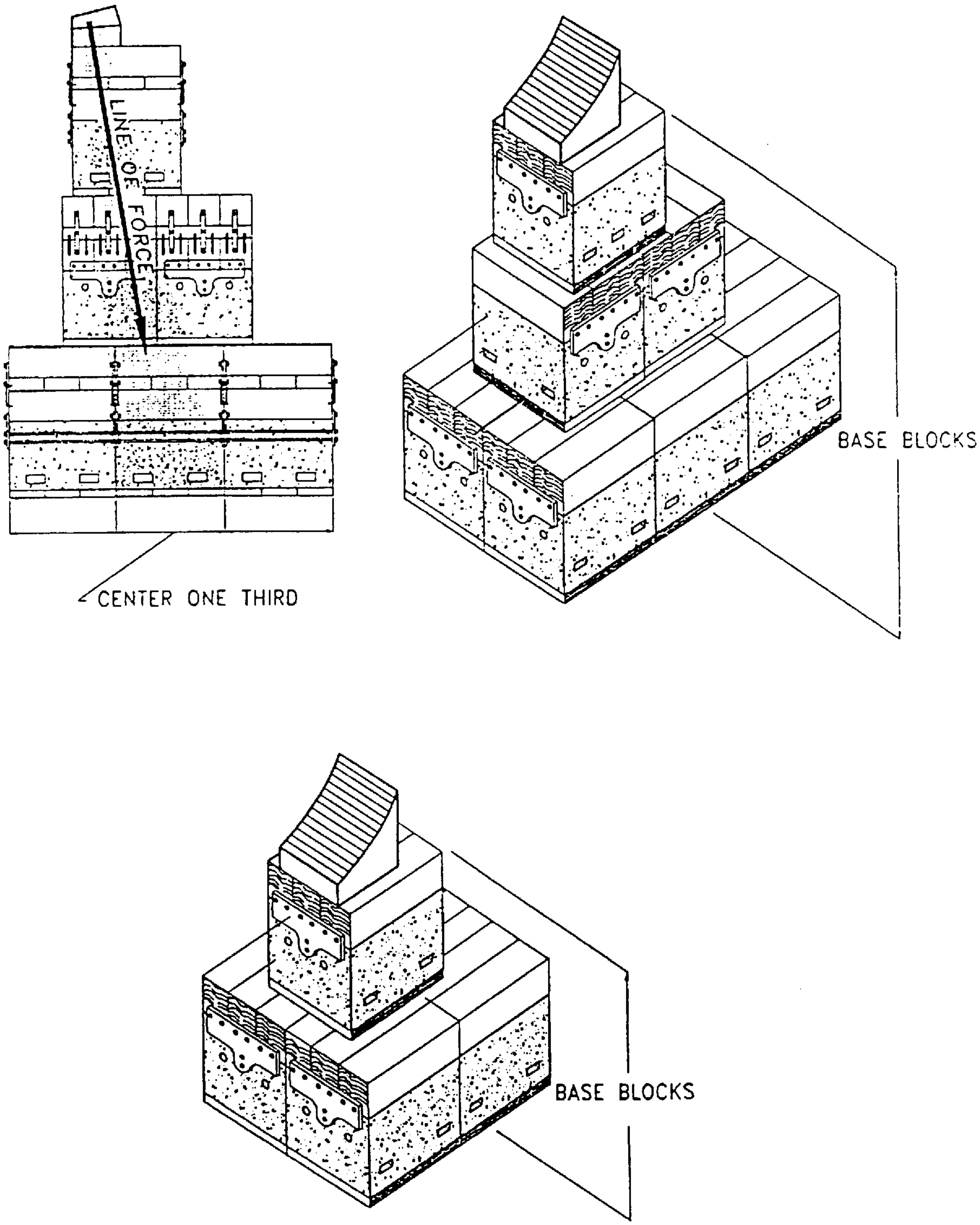


Figure 997-I-4. Pyramided Bilge/Side Blocks

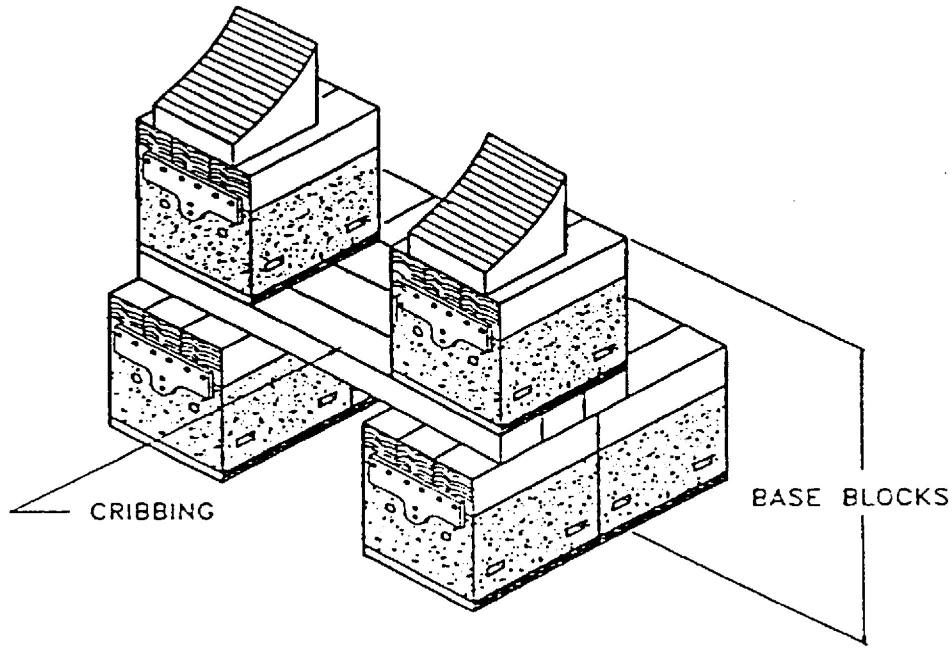


Figure 997-I-5. Fixed Cribbed Bilge/Side Blocks

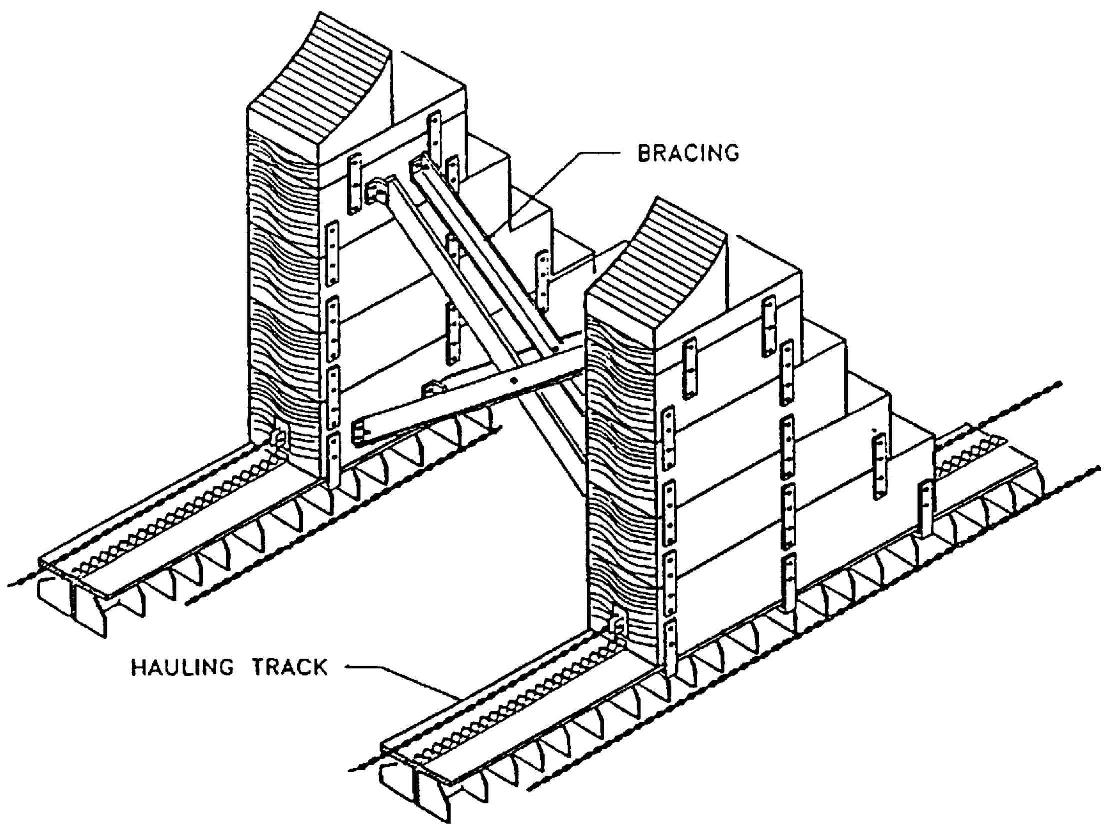


Figure 997-I-6. Haulable Braced Bilge/Side Blocks

APPENDIX J.

SYMBOLS

A	**Sail (side) area of the ship (ft^2)**
A_b	**Area of loaded blocks (in^2) or (ft^2)**
A_s	**Spur shore contact area (in^2) or (ft^2)**
A_1	**Area of one keel block (in^2) or (ft^2)**
A_2	**Effective contact area between side blocks and ship's hull (in^2)**
a	**Effective maximum horizontal earthquake acceleration imparted to ship (ft/sec^2)**
B	**Beam of ship (ft)**
b	**Distance from LCG to LCB of ship at any instant during pump down (ft)**
C	**A constant (defined within context of particular subject)**
C_a	**Allowable additional compression (in)**
C_b	**Center of buoyancy (Figure 997-2-1)**
C_c	**Constant (sample values given in Table 997-2-4)**
C_{KN}	**Compression of knuckle block (in)**
C_L	**Centerline of ship**
C_y	**Compression which occurs before soft wood yields (in)**
C_1	**Constant (see Table 997-2-4) (ft-ton)/in**
C_2	**Constant (see Table 997-2-4) (ton/in)**
D	**Draft of ship (ft)**
DL_s	**Dead load addition to side block load (tons)**
δD	**Difference between the midship drafts port and starboard (ft)**
d	**Distance from LCG to resultant knuckle reaction (ft) or minimum dimension of spur shore cross section (in)**
E_1	**Modulus of elasticity of spur shore (lb/in^2)**
e	**Fore and aft length of block (ft)**
FL	**Full load**
FP	**Forward perpendicular**
G	**That point which describes the center of gravity of the ship (see Figure 997-2-2)**
G_v	**That point which describes the virtual center of gravity of the ship at waterline W_1 L_1**
GG_v	**Virtual rise in center of gravity (ft)**
GM	**Metacentric height (ft)**
G_v M_1	**Virtual metacentric height at waterline W_1 L_1 (ft)**
g	**Acceleration of gravity (32.2 ft/sec^2)**
H_1	**Mean draft at landing (ft)**
H_A	**Draft aft (at aft draft marks) (ft)**
H_D	**Deep draft (ft)**
H_F	**Draft forward (at forward draft marks) (ft)**
H_m	**Mean draft of waterborne ship (ft)**

h Clear space between blocks (ft)

KG Height of center of gravity of ship above keel when waterborne (ft)

KG_A Height of center of sail area above keel (ft)

KG_v Virtual height of center of gravity above keel (ft)

KM Height of metacenter above keel (ft)

KM_1 Height of metacenter above the keel at instability (ft)

K_1 Spring constant of spur shore (lb/in)

K_2 Spring constant of side block (lb/in)

k Constant (see paragraph 997-2.5.4.3.2)

L Length between perpendiculars (LBP) (ft)

L_c Length of keel blocks in contact with ship's keel (ft)

LCB Longitudinal center of buoyancy

LCF Longitudinal center of flotation

LCG Longitudinal center of gravity

L_{cs} Length of constant stress from the knuckle forward (ft)

L_k Length of keel in contact (ft)

L_1 Average moment arm of spur shores reaction (ft) (see Figure 997-2-1 , Figure 997-G-1 and Figure 997-G-3)

L_2 Average moment arm of side block reaction (ft) (see Figure 997-2-1, Figure 997-G-1 and Figure 997-G-3)

L_3 Length of spur shore (ft)

M Overturning moment (ft-lb) = M_s or M_h (whichever is greater)

M_h Hurricane overturning moment (ft-lb)

M_s Seismic overturning moment (ft-lb)

MT1″ Moment to trim 1 inch ((ft-tons)/in) See note.

M_1 Metacenter of waterline W1L 1 (ft) (see Figure 997-2-2)

N_1 Number of spur shores required on each side of ship

N_2 Number of side blocks required on each side of ship

n Number of blocks in contact with keel

P_{KN} Pressure at aft end of knuckle block averaged over entire width of block (lb/in^2)

P_s Pressure at which soft wood yields without permanent deformation (lb/in^2)

R_{kb} Load on knuckle block (tons) See note.

R_{KN} Knuckle reaction (tons) See note.

R_1 Average shore reaction (lb) (see Figure 997-2-1 and Figure 997-G-3)

R_2 Average side block reaction (lb) (see Figure 997-2-1, Figure 997-G-1 and Figure 997-G-3)

S Allowable unit stress at aft end of knuckle block disregarding stress concentrations under narrow keels or skegs. Stress concentrations are considered by varying S for different types of ships (lb/in^2)

S_{ave} Average stress in a block or number of blocks (lb/in^2)

S_c Safe column stress (for spur shores) (lb/in^2)

S_k Keel slope (ft/in)

S_p **Strength at proportional limit of block material (lb/in^2)**
S_s **Stress in spur shore (lb/in^2)**
Sta **Station spacing (ft)**
S_1 **Stress at forward edge of first block (knuckle block) (lb/in^2)**
S_2 **Stress at aft edge of second block (lb/in^2)**
S_3 **Stress at forward edge of second block (lb/in 2)**
S_4 **Stress at aft edge of third block (lb/in^2)**
S_5 **Stress at forward edge of third block (lb/in^2)**
T **Period of roll for one complete cycle, port to starboard to port (sec)**
TP1″ **Tons per 1 inch immersion at the mean draft (tons/in) See note.**
T_{re} **Trim remaining (ft)**
T_{tr} **Change in trim (ft)**
t **Total trim [ft or (rarely) in]**
t_c **Thickness of the cap (in)**
t_a **Allowable trim between perpendiculars (for most ships this is essentially the same as the trim between draft marks) (ft)**
V **Velocity of wind (knots)**
W **Ship dead load (tons)**
W_b **Block width (ft)**
W_k **Width of keel (ft)**
WL **Waterline (waterborne)**
W_1 L_1 **Waterline under consideration during pumpdown (Figure 997-2-2)**
X_{KN} **Distance from knuckle block to longitudinal center of flotation (ft)**
Z **Offset correction at the waterline for heeled ship (ft)**
Δ **Displacement of ship (tons) See note.**
(Δ-R_{KN}) **Residual buoyancy at waterline W_1 L_1 under consideration (tons) (Figure 997-2-2)**
Theta **Angle of heel (degrees)**
NOTE: **All tons are long tons (2240 lbs = long ton)**

REAR SECTION

NOTE

TECHNICAL MANUAL DEFICIENCY/EVALUATION EVALUATION REPORT (TMDER) Forms can be found at the bottom of the CD list of books. Click on the TMDER form to display the form.